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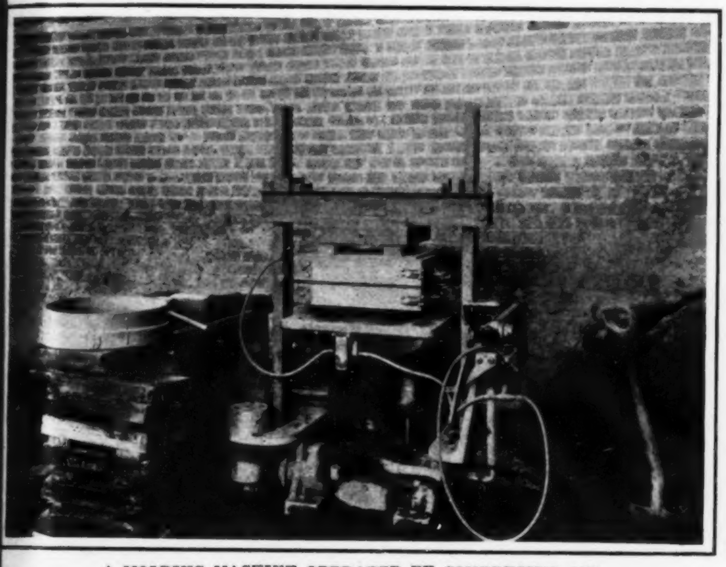
PNEUMATIC TOOLS IN IRON FOUNDRIES.

By Frank C. Perkins.

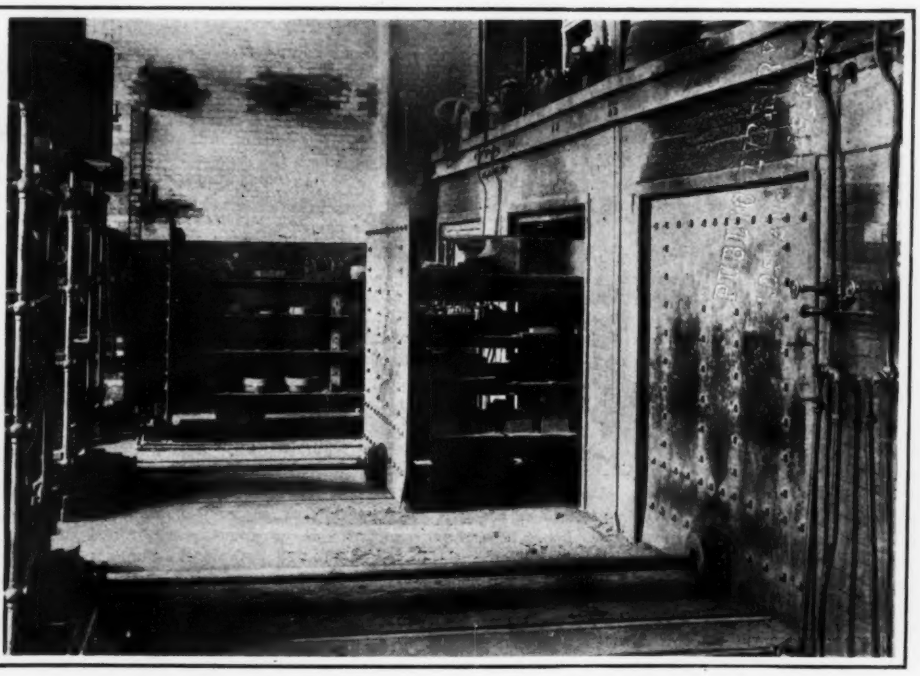
While electricity is more universally used for oper- g labor-saving devices and various machine tools d other apparatus than any other form of power, in



A MOLDING MACHINE OPERATED BY COMPRESSED AIR.

SAND-BLASTING CASTINGS WITH COMPRESSED AIR.

THE PNEUMATIC JIB CRANE FOR FOUNDRY SERVICE.



PNEUMATICALLY-DRIVEN CORE-OVEN CARS.

PNEUMATIC TOOLS IN IRON FOUNDRIES.

ny instances compressed air can be utilized to ater advantage. In other cases hydraulic power is re desirable, where machines, such as presses in at forging shops, require enormous pressures.

n iron foundry service compressed air is utilized operating various tools to great advantage. Where tric power is available, it may be employed for ving the compressors which supply the air to these ls.

One of the accompanying illustrations shows the thod of sand-blasting castings by compressed air to ove adhering sand. Another illustration shows a crane equipped with a compressed-air cylinder, ile a third picture shows some core ovens operated compressed air. Pneumatic power is employed for pushing the cars into and out of the ovens. Three such ovens are shown in the illustration, the two in the background having their cars loaded with cores and partly and fully withdrawn from the oven, while the one noted in the foreground in closed. The opening of the doors and drawing out of the cars is controlled by valves, as shown at the right in the illustration. As indicated, each car is fitted with a shield at one end, forming a door which closes the oven as the car runs in on the rails provided. A long horizontal cylinder is provided in which compressed air acts on a five-inch piston, the piston rod operating the car. By opening a valve, air is admitted behind the piston and pushes the heavy car loaded with green cores into the oven, these cars being withdrawn when the cores are baked. To do this it is necessary only to open another valve admitting air to the other side of the piston.

The pneumatic jib crane shown is provided with a compressed-air cylinder, which gives a positive but perfectly smooth control of the lead on the crane. This is of vital importance in assembling the different sections of a flask quickly and with ease. Jarring and sudden movements are avoided, with the result that the mold is not likely to sustain injury.

Another important use of compressed air which is absolutely necessary in a foundry is the air-blast for the cupola in which the various kinds of pig iron are melted. The forced-air draft as supplied by the blowers, as well as the heating and ventilating fans, may readily be considered as pneumatic or compressed-air devices, and the blowers as well as the air compressors may be driven to great advantage by either alternating or direct current motors.

In the iron foundry in which the various devices here illustrated are used, there may also be seen an electrically-driven air compressor, which is capable of supplying 1,700 cubic feet per minute. The machine is driven by a 225-horse-power motor of the synchronous type with current of 10,000 volts pressure.

In the foundry in question compressed air is utilized to a very large extent, supplied through piping at a pressure of 80 pounds per square inch. One of the accompanying illustrations shows one of more than

threescore molding machines operated by compressed air. These machines make a large number of molds from a great variety of patterns for castings up to 100 pounds or even 500 pounds in weight. For pneumatic molding machines compressed air is utilized to great advantage for three purposes. First, for ramming the sand about the pattern, the air being piped to an inverted vertical cylinder, the plunger of which is fixed in the lower part of the machine. With the pattern in place in the "drag" or lower part of the flask, or in the "cope" or upper part, the workman operates a lever valve, and air is then admitted below the cylinder.

Upward blows are struck on the bottom of the flask, the force of which blows is controlled to a nicety. It is maintained that two or three blows delivered in this way thoroughly tamp the sand about the pattern as well as it could be done by hand. There is a great saving of time, and therefore an increased output. For the second use of compressed air another valve is provided, which when opened admits air to the vibrator, sharply raps the side of the pattern, and quickly loosens the pattern from the sand, so that it may be lifted out of the mold with perfect ease. Compressed air is also used for the third purpose of blowing the loose sand away from the mold, this being a far more satisfactory way than brushing or any other method which might injure the mold.

It will thus be seen that while electric power is almost a universal force in machine shop and factory service, compressed air has its own field of usefulness which is recognized particularly in the modern iron foundry.

THE ACTION OF OXYGEN ON METALS.

A VALUABLE STUDY.

BY EDUARD JORDIS AND W. ROSENHAUPT.

ALTHOUGH the action of the various constituents of the atmosphere—oxygen, water vapor, carbon dioxide, sulphurous acid, sulphureted hydrogen, ammonia, ammonium sulphide, and the oxides of nitrogen—on copper, tin, zinc, and their alloys is of great practical importance, it has never been studied systematically. Our own experiments (with one exception) have been confined to the action of pure oxygen and moisture at various temperatures. The effect of oxygen collected over water was in most cases determined simultaneously with that of the same gas nearly, though not absolutely, dried by sulphuric acid and calcium chloride.

The metal, freed from grease and oxide by washing with absolute alcohol and acetic acid, was placed between asbestos plugs in a glass tube 20 inches long, the open end of which was then drawn out into a capillary neck 4 inches long. The tube was exhausted by a mercury air pump and filled with oxygen through a measuring burette, with or without the intercalation of drying tubes. In order to remove every trace of other gases, the tube was again exhausted and refilled with oxygen before it was put in the oven.

The oven was a sheet-iron box covered with asbestos felt, except at the bottom, under which was a triple gas burner. Eight holes in each end served as supports for eight tubes, which lay with their ends protruding from the box. Thus four pairs of experiments (with dry and moist oxygen) could be conducted simultaneously. Each tube was connected with a simple gage—a pipette dipping in water or glycerine—by which the volume of oxygen absorbed by the metal could be determined. Three holes in the top of the oven allowed a thermometer to be inserted, and its bulb placed near the middle or either end of the upper or lower row of tubes. With this crude apparatus variations of 18 to 45 deg. F. were observed at the same part of the oven in long periods of heating, and the simultaneous differences between different parts were still greater. The temperatures were observed at least twice daily.

The oven was first heated continuously during a period of (usually) from 100 to 200 hours, measured quantities of oxygen being admitted through the gages as required to replace the loss by oxidation. The oven was then allowed to cool over night, and on the following day the gages were filled to the reference marks. The sum of the volumes of oxygen admitted since the commencement of the experiment, corrected for variations of thermometer and barometer, gave the quantity consumed in oxidation. Another period of heating followed, and so on. The sum of the heating periods ranged from 350 to over 1,600 hours. In the longer experiments the tubes were evacuated and refilled with oxygen after about 500 hours, to eliminate any impurities that might have leaked in.

The metals tested were pure copper, zinc, and tin, a specially made bronze, and several commercial specimens of brass.

With copper, four pairs of experiments were made with dry and moist oxygen and one experiment with dry air. In the first pair of experiments the dry tube remained four days and the moist tube thirty-seven days at room temperature, without showing any change in the appearance of the metal or the reading of the gage. On heating the dry tube the contents (48 grammes of copper filings) darkened, and the gage rose so rapidly that after ten hours it was necessary to admit 33 cubic centimeters of oxygen. But the rate of oxidation fell off rapidly. When the tube was cooled after being heated to about 290 deg. F. for 150 hours, it was found that 44.5 cubic centimeters of oxygen had been consumed—about 30 cubic centimeters per 100 hours. The tube was evacuated, refilled, and heated to 285 deg. F. for 445 hours. In this second period the consumption was only 3.6 cubic centimeters per 100 hours.

Then the tube, which had cracked, was opened, and the filings were found sintered together. They crumbled under pressure and showed the metal. They were put into another tube and heated to 316 deg. F. The baring of the metal caused rapid oxidation, but this soon diminished, so that the average absorption during the third period (of 509 hours) was only 4.6 cubic centimeters per 100 hours. The filings (49 grammes) which were heated in moist oxygen showed a greater variety of colors—white, red, violet, yellow, and blue—before reaching the final red-black tint. The rate of absorption was 12 cubic centimeters per 100 hours in the first period, of 331 hours, at 277 deg. F., and 3.3 cubic centimeters per 100 hours in the second period, of 508 hours, at 316 deg. F. In both experiments the oxidation, rapid at first, diminished as the coating of oxide increased in thickness, as shown by its change in color. When the oxide was partially removed (in the transfer occasioned by the accident) the parts laid bare were quickly oxidized, and then the permanent state of slow oxidation was restored. Hence the protective effect of the coating of oxide is manifest. A striking result, contrary to expectation, was the slower and smaller action of the moist oxygen.

The second pair of experiments, with about 55.5 grammes of copper filings in each tube, gave very similar results in its first four periods, aggregating 1,030 hours of heating to about 266 deg. F., the consumption per 100 hours falling from 11 cubic centimeters of dry and 9 cubic centimeters of moist oxygen in the first period to 2 cubic centimeters of each in the fourth period. The temperature was then raised to 464 deg. F. The rate of oxidation at once increased greatly, and for moist oxygen it thereafter remained nearly constant during the remaining four periods (450 hours), falling only from 25 to 21 cubic centimeters, while the rate for dry oxygen fell gradually from 23 to 12 cubic centimeters. In the last periods, therefore, the moist oxygen acted far more energetically than the dry.

In the third pair of experiments copper wire 1/250 inch in diameter was heated to 464 deg. F. during 450 hours. The wire oxidized rapidly at first, and turned quite black during the first period, of 49 hours. The oxidation was much greater and more rapid in moist than in dry oxygen. Each reheating produced a sudden acceleration of the rate, owing probably to cracks formed in the coating of oxide during cooling. In this and the next pair of experiments the consumption of oxygen can be estimated in cubic centimeters per square decimeter of surface per 100 hours. Thus expressed it was 9 of dry and 11 of moist oxygen in the first period of 49 hours, and thereafter nearly constant at 4 of dry and 4 to 6 of moist gas.

In the fourth pair of experiments copper foil 1/250 inch thick was heated to about 570 deg. F. during 450 hours. In the middle of the tubes the copper became black during the first period of heating, of 49 hours. In the last periods, especially in the moist tube, the oxide scaled off and exposed bright metal. For this reason, probably, the consumption of moist oxygen (in cubic centimeters per square decimeter per 100 hours), after falling from 15 in the first period to 9 in the second, rose to about 12 in the third and fourth, while the consumption of dry oxygen declined steadily from 5 to 2.

These experiments show that even a small quantity of moisture increases oxidation very greatly; and a still more surprising fact of the same order was learned from the next experiment, in which 50 grammes of copper filings were heated to nearly 300 deg. F. during 355 hours in dry air, freed of carbon dioxide by soda lime, the loss by oxidation being made good by admitting oxygen. Though the oxygen pressure was only 1/5 that of the first experiments with filings, the consumption of oxygen was much greater, namely, 34, 13, and 15 cubic centimeters per 100 hours in the three periods of heating. This result must be due to the formation of small quantities of oxides of nitrogen, which facilitate oxidation of the metal. These cannot be produced in large quantity in presence of metallic copper, hence little of the oxygen consumed was absorbed in their formation. This observation suggests an explanation for the effect of water vapor above a certain temperature. Possibly traces of hydrogen peroxide are produced, which facilitate oxidation of the metal.

In the oxidation of copper, in general, it is probable that a suboxide is formed which either is porous or is dissolved by the metal. Hence the rate of oxidation soon falls to a constant value equal to the rate at which the suboxide diffuses into the metal, and this rate is maintained until the whole mass is saturated with suboxide. Or the substance dissolved may be metallic oxygen or an alloy of oxygen and copper. In some cases brittle black oxide is formed at the surface and separates in flakes.

In the next experiment 39 grammes of tin filings were heated to nearly 300 deg. F. in dry oxygen during 264 hours, and then to 320 deg. F. in moist oxygen during 1,360 hours. The absorption of dry oxygen was very small, only 0.4 cubic centimeter per 100 hours. The absorption of moist oxygen was much greater, though still small, beginning at 5 cubic centimeters and gradually declining to 1 cubic centimeter. In the next pair of simultaneous experiments, with 50 grammes of tin filings in each tube, the consumption in 100 hours fell from 7 cubic centimeters in the second period to 4 cubic centimeters of dry and 3 cubic centimeters of moist oxygen in the last period of the 1,364 hours of heating.

In three similar experiments with zinc filings the oxidation was almost inappreciable except in the latter half of the pair of experiments, when the temperature was raised to 575 deg. F. The consumption in 100 hours then rose to 25 cubic centimeters of dry and 47 cubic centimeters of moist oxygen, and declined to 2 and 4.6 in the final period.

From all the experiments with pure metals it appears that copper begins to show oxidation colors at about 212 deg. F., tin at about 250 deg. F., and zinc at 350 deg. F. or over. These differences probably depend on the solubility of the oxide in the metal.

Brass foil containing 10 and 25 per cent of zinc absorbed only very small quantities (from 0.1 cubic centimeter to 1.6 cubic centimeters per square decimeter per 100 hours) of either dry or moist oxygen at temperatures from 314 to 432 deg. F. Brass foil containing 36.6 per cent of zinc, with traces of lead, iron, and magnesium, and approximately representing the definite alloy Cu_2Zn, absorbed 4 cubic centimeters of dry and 5 cubic centimeters of moist oxygen per square decimeter per 100 hours in the first period of 49 hours at 320 deg. F., after which the absorption was very small, even when the temperature was raised to 535 deg. F.

Very different results were obtained with shavings of a bronze made by melting 70 parts of copper with 30 parts of tin. The quantities of oxygen consumed by about 30 grammes of bronze (surface not estimated) per 100 hours were 65, 15, and 19 cubic centimeters dry and 50, 14, and 17 cubic centimeters moist in three consecutive 120-hour periods at 291 deg. F., and 56, 12, and 9 cubic centimeters dry and 77, 48, and 41 cubic centimeters moist in three similar periods at 530 deg. F. The results are directly comparable with those of the first experiments, with copper filings, and the comparison shows that the bronze was oxidized far more rapidly than the pure copper, and, like the copper, was affected more by dry than by moist oxygen at low temperatures, and the reverse at high temperatures. The more rapid oxidation of bronze may be explained by Bauer's discovery that suboxides of copper cannot coexist with tin, which reduces them to the metallic state. Hence in bronze only the tin is oxidized, yet the oxidation curve resembles that of pure copper, owing to the relatively great rapidity

with which the tin combines with oxygen. In brass, the copper curve showed only in the specimen containing the most copper (90 per cent), and here the oxidation was retarded, not accelerated, by the presence of zinc.

SUMMARY.

1. Systematic investigations of the action of gases on metals are lacking.

2. Neither dry nor moist oxygen affects copper, tin, zinc, or their alloys at ordinary temperatures. Copper is not appreciably oxidized below 140, tin below 212, or zinc below 356 deg. F.

3. Tin is more affected by moist than by dry oxygen at all temperatures. Copper and zinc are oxidized more rapidly by dry than by moist oxygen at low temperatures, but moist oxygen acts more energetically upon these metals than dry oxygen above 400 deg. F.

4. Air, although it contains only 21 per cent of oxygen, acts more energetically than pure oxygen on copper at 300 deg. F.

5. The superior oxidizing power of air and of moist oxygen is probably due to the presence in them respectively of oxides of nitrogen and peroxide of hydrogen, which act as oxygen carriers.

6. The course of the phenomena depends on the character and changes of the superficial layer, and oxidation ceases when this layer excludes oxygen from the metal.

7. A surface allowing the continuance of oxidation may exist:

(*a*) If oxygen or an alloy of oxygen is dissolved in the metal;

(*b*) If the adhering coating of oxide dissolves oxygen or is porous;

(*c*) If this coating consists of a suboxide susceptible of further oxidation;

(*d*) If the coating scales off.

Examples of all of these conditions were observed.

8. Definite alloys exhibit characteristic properties but an excess of either component gives prominence to the characteristics of that component.

9. Metal filings sinter and coalesce in the process of oxidation.

10. With suitable apparatus the proportions of metal and oxygen in the superficial layer could be determined from its color.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Zeitschrift fuer Angewandte Chemie.

WOMEN ENGINEERS.

THE OBSTACLES IN THEIR WAY.

BY KARL DREWS.

WRITERS and speakers who advise women to adopt the profession of engineering fail utterly to understand the magnitude of the obstacles which women engineers must surmount. Except for these obstacles, women engineers would have abounded long ago, for there is no legal prohibition of their employment, at least in private enterprises. In recent years, indeed, many women have been admitted as students to technical schools. Nor is there any legal or theoretical hindrance to the workshop practice that is a necessary part of the education of the mechanical and electrical engineer. There is nothing to prevent a woman working in a shop at lathe or forge, with saw, plane, chisel, etc.—except the physical fact that she is a woman.

In other words, the obstacles are not legal or artificial, like those which oppose the entrance of women into some other professions, but are inherent in the nature of the case and are due to woman's comparative weakness, both bodily and mental.

The work of the engineer is creative in the highest sense of the word. From his brain spring the marvels of modern industry; his thoughts are clothed with iron and steel. Intimately connected with this mental faculty of creation is a highly-developed physical faculty of spatial perception, or three-dimensional vision. Neither of these faculties is possessed by woman, whose notable performances have hitherto been confined to the reproductive arts. We have great actresses, singers, and instrumental players who rank with the most eminent of their male colleagues, but we have no great woman composer, painter, or sculptor. The creative ability of woman is most conspicuous in literature, but even here it is confined to poetry and fictional narration, yet the best of women novelists are surpassed by men. Women dramatists scarcely exist.

Still more fatal to woman's success as an engineer than her innate and acquired mental peculiarities is her bodily weakness. For it must be clearly understood that the road to the drafting board and the laboratory of the engineer lies through the workshop, and workshop practice means hard work and blistered hands, not dilettante pottering and observation. To quote an eminent English engineer: "Kid gloves are perfect non-conductors of technical knowledge." Many modern shops are attractive, well lighted and ventilated places, but the work done in them is work for men's hands; indeed, the huge machines and other objects demanded by modern requirements and made possible by improvements in methods, tools, and hoisting and transporting devices appear as if fashioned by the hands of giants.

It may be objected that workshop practice represents only a transient phase of the engineer's life, and that designing constitutes the chief part of his work. To many persons, indeed, an engineer is only a human calculating machine, but this view is entirely false. It is true that technical science has reached a very high stage of development, but we are not yet able to express everything in mathematical formulas. We continually have to make compromises between theory and practice, and the thing that appeared perfect in design may prove very imperfect in actual use. Hence the engineer must have, in addition to a good scientific education, much practical experience, which he can acquire only in workshops and industrial establishments and enterprises. The want of such practice often causes machines, etc., to be designed which cost three or four times the estimated amount.

The difficulties here indicated cannot be overcome by the most resolute and indefatigable of women. And the women of the lower class, inured to hard work, are not the ones who can devote themselves to the study of engineering.

Women engineers should be possible in America, if anywhere. A recently published census of American women engaged in technical occupations includes 409 electricians, 84 engineers, and 1,041 architects. In order to obtain some definite information on the subject I addressed a circular letter of inquiry to thirty-three of the leading American firms engaged in electrical work and machine building and to the four great technical societies of mechanical, electrical, civil, and heating engineers, from all of which I received courteous replies. The result of the inquiry is the following:

None of the firms employs women in engineering work, and many of them state expressly that they have no intention of doing so. A very large and well-known firm of engine builders replied that the character of its business forbade such experiments, but admitted that it had employed a woman graduate of Cornell University. Women were employed as draftsmen in American machine shops, but the firm knew of no woman possessed of the knowledge and experience that would justify her in calling herself an engineer. Nothing was said in regard to the work of the Cornell graduate. This silence is eloquent, especially as it was stated that the experiment would not be repeated.

An important electrical company replied that it employed no women as engineers, but that Miss Lamme, a sister of the chief engineer of the Westinghouse Company, had for several years made computations for direct-current motors for that company. "But she has preferred an appointment as wife to her position as engineer," the writer adds. This lady's work falls within the engineer's province, but it must be remembered that engineering calculations are carried out according to a schedule, and require familiarity with routine rather than extensive experience. As her work was purely mathematical she cannot, strictly speaking, lay claim to the title of engineer. It may be admitted without argument that women appear well fitted for this limited field of work.

The American Society of Mechanical Engineers replied that the number of practising women engineers was very small, and that the writer knew of only two cases.

The American Society of Heating and Ventilating Engineers was kind enough to make inquiries of a college professor, a leading technical school, and a technical journal. The result was about as follows: Although many women study electrical engineering and machine design, the number of women actually engaged in genuine engineering work is exceedingly small. Only two were specially mentioned, both graduates of Cornell. One (whom I shall have occasion to mention again) was employed by a firm in Rochester, the other by a railroad in China.

The reply of the president of the technical school is to the effect that in the engineering profession women may be valuable assistants, but nothing more, because of their almost inevitable lack of workshop practice. The letter concludes (literally) with the following words:

"I do not think women are naturally adapted for engineering professions, because their nature is such that they cannot get through the hard school of manual labor and practical experience in workshops, which is so essential in the training of an engineer. I know that women can be educated in the theory of design, and that they can make drawings and tracings, in many cases superior to men, but the constructive faculty so essential to good design, and the management of men, so essential in the erection of work, are not prominent features in the make-up of a woman."

But there is no rule without an exception. The Deane Steam Pump Company, of Holyoke, wrote that Miss Kate Gleason, a daughter of the proprietor of the Gleason Works in Rochester, N. Y., had enjoyed a thorough education in the practice as well as the theory of engineering. Among other things, she had superintended the installation in Europe of several machines built by the Gleason Works, of which she had become a director, after having acted as chief engineer in several departments. She enjoyed a high and well-deserved reputation as an engineer. This is a rare, probably a unique case. It is not astonishing that women endowed with typically masculine, and hence abnormal, talents should appear now and then. It must be borne in mind, too, that Miss Gleason has apparently been enabled to develop her engineering talent in extraordinarily favorable conditions. It would be absurd to draw any general conclusions from this individual case.

The general result of my inquiry can be summarized in the statement that in America many women study electrical engineering and machine design in the technical schools, but that very few women are practising engineers.

They appear to be more successful in architecture, especially in interior architecture, which supplies an appropriate field for the artistic talents of intelligent women. According to the letter of the American Institute of Electrical Engineers, several women architects are employed by the United States government.

Many of the replies discuss the employment of women as draftsmen. On superficial consideration of the subject it would naturally be expected that American firms would employ cheap female labor extensively for tracing and stenciling, which are purely mechanical operations, apparently requiring no technical skill. But my American correspondents inform me that very few tracing girls are employed in machine shops. This is not at all surprising. I said above that the purely mechanical operations of drafting apparently require no technical training, but as a matter of fact they do require a certain amount of technical knowledge, sufficient to understand the drawings, the operations of the workshop, etc. Without this knowledge, which can be acquired only in the workshop, a draftsman cannot produce a true drawing, and his (or her) work will contain so many errors that its revision and correction by a competent person will cost far more than is saved by employing the cheaper labor of women. These conclusions are fully confirmed by the experience of some German firms who have employed women assistants.

The American attitude toward hard physical labor by women is expressed in the reply of the American Institute of Electrical Engineers. In the United States census I found enumerated some women boiler makers. Amazed at this, I mentioned the matter in my circular letter. The secretary of the above-mentioned association indignantly denied the statement in the census report and concluded with the words: "As a nation, we are proud of our chivalrous attitude toward women. We honestly believe we are too chivalrous ever to permit any woman to attempt to earn a livelihood in a boiler-making shop."

If women cannot succeed as engineers in America, where they enjoy the greatest freedom, still less can they do so in the Old World. If the only difficulties to be overcome were those of the workshop, Russian women should be the first to enter this field, hitherto monopolized by men. Russian women students may appear repellent in some respects, but we must, at least, admire the courage, often rising to heroism, with which they endure physical burdens and suffering. The revolutionary movement in Russia furnishes

examples enough. In this neither German nor American women can rival them, nor do we wish them to. The Russian government had in view the establishment in St. Petersburg of a technological institute for women, which should include courses in architecture and electro-chemistry. War, revolution, and lack of funds appear to have caused the project to be abandoned.

But even if women should succeed in overcoming all difficulties, I fear they will not feel at home in the associations entailed by the practice of engineering.—Die Umschau.

BOILER BLOW-OFF CONNECTIONS.*

A DESCRIPTION OF VARIOUS SYSTEMS.

BY R. T. STROHM.

THE various impurities that are carried into the steam boiler in the feed water and that are left there by the subsequent evaporation of the water give rise to the necessity of periodical cleaning. But thorough cleaning of all the interior surfaces and water passages involves the shutting down of the boiler and the cooling of its setting, a matter which is of no small importance in a plant where cutting out a boiler is followed by a decrease in output and a pecuniary loss.

To obviate the necessity of opening up the boiler so frequently and thus wasting valuable time, methods have been devised whereby foreign matter may be drawn off from time to time without interfering with the regularity of working of the plant.

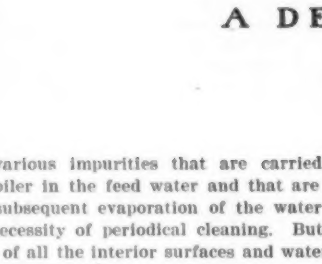


FIG. 1.—SIMPLE FORM OF SURFACE BLOW-OFF.

The impurities in feed water, having once entered the boiler, will manifest themselves in one or both of two ways. Those that are light and flocculent will float on the upper surface of the water, and the heavier ones will sink to the bottom. As a consequence, it will be found that there are two distinct systems by which such impurities may be removed. One of these is the surface blow-off, and the other the bottom blow-off. Each consists of piping so arranged that at any desired moment the accumulated foreign matter may be blown out by the pressure in the boiler.

The simplest form of surface blow-off would consist of some such arrangement as that shown in Fig. 1, in which a small pipe, *a*, fitted with a valve, *b*, is screwed into the rear head of the boiler at the water level, a pan, *c*, being fixed inside to collect as much of the floating matter as possible and hold it near the outlet. By opening the valve *b* at intervals and for short periods the impurities could be easily discharged. Such an arrangement is objectionable, however, in several respects. The pipe *a* is not a large one, and if the water level falls to any great extent, the outlet will be wholly uncovered, so that upon opening the valve, *b*, only steam would escape. Again, this device would be intermittent in its action, depending upon the care or thoughtfulness of the attendant.

As an improvement on such a crude system, the continuous automatic surface blow-off or skimmer was devised. Fig. 2 shows an apparatus of this kind. It consists of three skimming funnels, *a*, that open, at their small ends, into the discharge pipe, *b*, leading into the lower chamber, *c*, of the blow-off tank, *d*. The

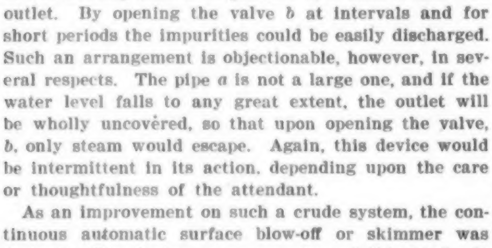


FIG. 2.—AUTOMATIC SURFACE BLOW-OFF.

foreign matter is caught at the surface of the water in the boiler by the funnels and is carried to the chamber, *c*. From this point the water rises through the filtering material, *e*, leaving the sludge behind in the bottom of the tank, *d*, from which it may be blown by opening the valve *f*. The filtered water passes upward into the chamber, *g*, and thence to the boiler through the pipe *h*. A continuous circulation takes place throughout this system when the boiler is in service, and hence the skimming action is uninterrupted and independent of outside attention. Moreover, the hot water carrying the sludge to the settling tank is returned to the boiler, purified, and there is no loss of heat beyond that due to radiation.

The device in Fig. 2 would become inoperative if the water level should rise above or fall below the mouths of the funnels, and they are made wide to allow of some fluctuation. The arrangement in Fig. 3, however, provides for any change of height of the water level, since the single funnel, *a*, is fitted with a pair of floats, *b b*. The discharge pipe has a swinging joint at *c*, by virtue of which the floats are enabled to keep the funnel always at the level of the water. The remainder of the system differs only in details from the one already described and the principle of action is the same.

The method of arranging the bottom blow-off will depend on the type of boiler. Obviously, the blow-off pipe must be connected at a point where the scale and sludge would naturally collect, which would be at the lowest point of the water space. Another reason for locating it at the lowest point is that the blow-off must serve as a means of draining the boiler completely when it is desired to inspect it internally.

The ordinary return tubular boiler gives greater difficulty in the location and protection of the blow-off pipe than any other type of boiler. As ordinarily set, the rear end of the boiler is an inch or so lower than the front end, and the blow-off pipe is screwed into the

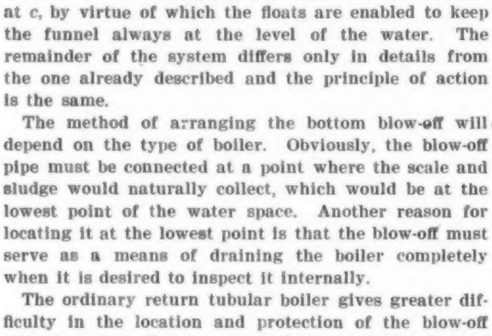


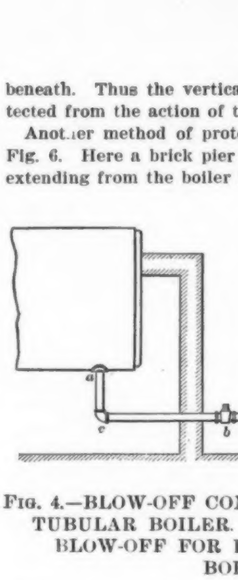
FIG. 3.—FLOATING SKIMMER FOR SURFACE BLOW-OFF.

under side of the shell plate at the rear, as at *a* in Fig. 4. The circulation in the return tubular boiler is such as to cause much of the scale to settle near the blow-off pipe, from where it may be blown out by opening the cock *b*.

However, it must be remembered that, with the blow-off pipe connected at *a*, it is directly in the path of the hot gases as they pass from the furnace to the tubes. Further than this, the blow-off is used intermittently and there is no circulation of water in the pipe. As a consequence, trouble is certain to arise unless reasonable precautions are taken to prevent it. With the arrangement shown in Fig. 4 it would be only a matter of time before sediment would collect in the elbow, *c*, where it would be baked hard by the intense heat and lack of circulation. The elbow and the vertical pipe would then rapidly clog with scale, and this scale would further prevent the heat from being transmitted to the water in the pipe. As a result, the pipe would be burned out, and would have to be replaced. That such trouble as this is very real and not uncommon may be inferred from the fact that some engineers have had to renew the bottom blow-off pipe as frequently as once in six weeks. Hence the need of proper protection of this important fitting.

First of all, the elbow should not be in the path of the hot gases. The arrangement shown in Fig. 5 will accomplish this, since the bend is beneath the floor of the setting, where it is protected by the brick and soot covering it. The blow-off pipe, *b*, is inclosed in a larger pipe, *a*, the space, *c*, between them being filled with mineral wool or asbestos. Outside of all, a third pipe, *d*, is placed, reaching from the shell to the floor beneath. Thus the vertical pipe, *b*, is completely protected from the action of the flames and hot gases.

Another method of protecting this pipe is shown in Fig. 6. Here a brick pier is built up around the pipe, extending from the boiler to the floor. The bricks are



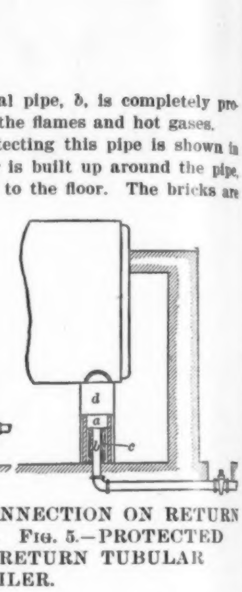


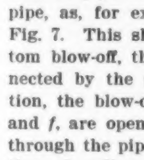
FIG. 4.—BLOW-OFF CONNECTION ON RETURN TUBULAR BOILER. FIG. 5.—PROTECTED BLOW-OFF FOR RETURN TUBULAR BOILER.

laid carefully in a mortar of fireclay and the whole is covered with a layer of fireclay after being built. This is a simple and effective way and is much used. Sometimes, instead of a rectangular pier surrounding the pipe, a V-shaped guard is built, with the point toward the front of the boiler. This is open at the rear, however, and is not so good as the inclosing brickwork. Still another way of preventing the pipe from burning out is to wrap it tightly and thickly with asbestos rope.

The manner of connecting the vertical pipe to the boiler should be carefully observed. It is not satisfactory to screw the pipe directly into the plate, for the plate may be too thin to enable a good connection to be made. Instead, a steel flange should be riveted to the boiler, and the blow-off pipe attached to this. Also, the pipe should be free to have a reasonable amount of expansion, which demands that it shall not be fixed too tightly in the rear wall or in the floor of the setting.

An additional means of prolonging the life of the blow-off pipe is to maintain a circulation through the pipe, as, for example, by the arrangement shown in Fig. 7. This shows a combination of surface and bottom blow-off, the discharge pipes, *a* and *b*, being connected by the riser, *c*. When the boiler is in operation, the blow-off cock, *d*, is closed and the valves, *e* and *f*, are open, and there is a continuous circulation through the pipes, *a*, *b*, and *c*, that prevents the collection of sediment in, and overheating of, the bottom blow-off pipe. When it is desired to use the surface blow-off, the valve *e* is closed and the cock *d* is opened. When the bottom blow-off is to be used, the valve *f* is closed and the cock *d* opened.

In all cases where the blow-off pipe is exposed to



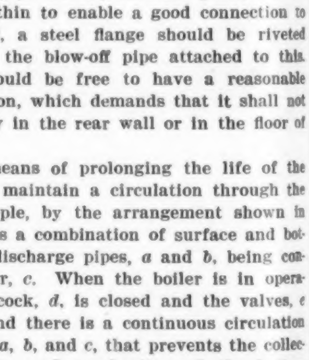


FIG. 6.—PROTECTED BLOW-OFF. FIG. 7.—SURFACE AND BOTTOM BLOW-OFF CONNECTION.

the hot gases it should be made of extra heavy pipe in order to reduce the chances of failure. In fact, many specifications name extra heavy pipe whether there is any protecting device to be used or not.

Where there are several boilers in service, it is not unusual to find them connected to a common blow-off main leading to the sewer. This is a questionable practice, inasmuch as it may become dangerous. Suppose that, while one boiler of the battery is open for inspection, the blow-off cock on one of the others should be

* Electrical World.

opened. The consequences to an inspector inside the idle boiler would be terrible. This is no hypothetical case. Accidents of precisely this character are on record. Evidently the safe plan is to have each boiler discharge through its own pipe.

In the Babcock & Wilcox water-tube boiler as illustrated in Fig. 8, the water is forced into the upper drum through the feed pipe *a*. The circulation then is downward through the risers, *b*, upward toward the front header through the tubes, *c*, and thence back to the rear in the drum above. The rear header is connected to a mud drum, *d*, that forms the lowest part

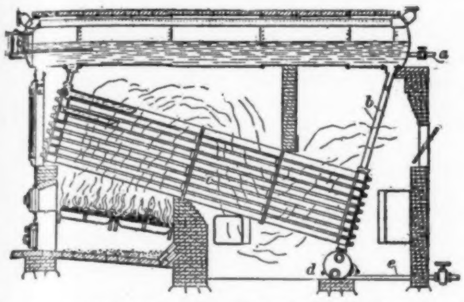


FIG. 8.—BLOW-OFF CONNECTION OF BABCOCK & WILCOX BOILER.

of the water space. To this drum the blow-off pipe, *e*, is attached.

The Heine boiler, also of the water-tube type, has a double blow-off system. The usual bottom blow-off is provided at *a*, the lowest part of the rear water leg. An auxiliary blow-off, however, is installed at *b*. Suspended inside the steam drum, beneath the water, is a long drum, *c*, closed at the rear end but open at the front. Into this drum the feed pipe, *d*, discharges, and thus the incoming feed water is heated to nearly the temperature of the surrounding water before it begins to circulate through the tubes. The result is that a large part of the soluble impurities are precipitated in the drum *c*, from which they are removed at intervals by the opening of the valve at *b*.

The Stirling water-tube boiler, differing in design from either of the foregoing, is shown in Fig. 10. The feed water enters the rear upper drum at *a*, passes downward through the tubes *b* into the mud drum, *c*, and thence upward through the other tubes. At the bottom of the drum the blow-off pipe, *d*, is attached.

In the case of the Cahall vertical boiler, consisting of upper and lower drums connected by tubes almost vertical, as in Fig. 11, the lowest part of the water space is at the bottom of the drum, *a*, and this is the logical point of attachment of the blow-off pipe, *b*. Had the boiler been a fire-tube instead of a water-tube, the blow-off pipe would have been connected to the water leg at its lowest point.

THE THEORY OF HIGH SPEED TOOL STEEL.*

By GEORGE AUCHY.

IMPROVEMENT in metallurgical processes has been almost entirely a record of achievement by practical men, unaided by theorists. Rarely, if ever, has the chemist or the theoretical metallurgist blazed the way, but has for the most part contented himself with following in the rear of practical accomplishment, explaining the reason for it all. The development of high speed tool steel has been no exception to this rule. From first to last it has been accomplished by practical metallurgists. But yet the theoretical metallurgists have not been idle—they have indeed

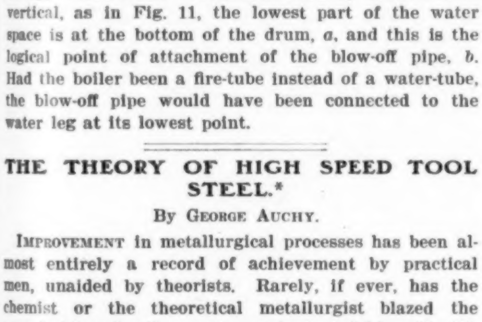


FIG. 9.—BLOW-OFF CONNECTION OF HEINE BOILER.

followed up their practical brethren so closely that the manufacture of high speed steel has hardly settled down to a permanent groove before the theory of the phenomena connected with it is completed and ready. This theory has gradually unfolded itself under the master hands of Osmond, Böhler, Le Chatelier, Carpenter, and others, and to the labors of these investigators the monumental work of Dr. Guillet has been a fitting climax, so that now the general theory would seem to stand out clearly and distinctly. Now that the theory is at hand, it would be interesting and instructive perhaps to compare theory with practice, and see how far the one is corroborated by the other, and how the composition of high speed steel indicated by theory to be the best, agrees with the "mix" almost universally in actual use in the steel trade.

In reviewing the theory, to start at the beginning, we must consider briefly the conflicting theories of the constitution of steel at different temperatures evolved by Mr. Osmond on the one hand and Prof. Arnold on the other. According to the former authority, iron or steel exists in three allotropic conditions, which he designates alpha, beta, and gamma: In mild steel, alpha up to 720 deg. C.—750 deg. C. (Arnold); beta between these points and 810—830 deg. C., and gamma above these last temperatures. Alpha iron is soft, beta is very hard, and gamma medium hard. But in pure iron the beta and gamma forms can never be retained in the cold. Quench as rapidly as we may, the beta and gamma conditions change to the alpha ahead of us. But when carbon is present in sufficient quantity it "acts as a brake" on this transformation, and we can then trap the beta condition by quenching or rapid cooling, but still not the gamma, except by quenching at more than 1,000 deg. C., and then only partially and mixed with martensite (beta iron).

We can obtain the gamma condition with ease and certainty by alloying with the iron another metal (manganese, nickel, chromium, tungsten, or molybdenum), but the alloys of the last two must first be heated to 1,200 deg. C. to destroy the double carbide first formed. Chromium also forms double carbide (if very high) in large quantity, in which case the gamma condition can be obtained without quenching—the steel is "self-gamma," so to speak—and is stable at ordinary temperatures if not verging too closely on the beta. In steels in the alpha condition the iron and carbon are combined as carbide of iron or cementite. This cementite in high carbon steels (over 0.95 per cent) exists in two different forms, according to Prof. Arnold physically different but of the same chemical composition, Fe_3C, as free cementite and as cementite intimately mixed with ferrite (pure iron), to form what is known as pearlite. But in steels where the carbon is under 0.95 per cent all the cementite is in the pearlitic form—that is, it is intimately mixed with ferrite—and there is no free cementite, but free ferrite instead.

When the steel is heated to over 710 deg. C., the carbide of iron or cementite, either free or pearlitic, is decomposed or dissociated into iron and carbon, the latter existing in a condition of solid solution in the former, while the steel is in the beta condition, and also while it is in the gamma condition, returning to the carbide condition only when the steel returns to the alpha condition, which it does on slow cooling. The solid solution of carbon in beta iron is called martensite, the distinctive constituent of hardened steels, and the solid solution of carbon in gamma iron is called austenite, and is not so hard as martensite, and is tough instead of brittle. Alpha iron is magnetic. Beta and gamma are not magnetic.

The theory of Prof. Arnold denies that there is any proof of the existence of three allotropic forms of iron and ascribes the difference in the properties to difference in the chemical composition of the carbide, which, according to him, is never normally dissociated into its original elements at any stage of heating in the case of steel, although this point of dissociation is one which the allotropists do not insist on. On the contrary, such high authorities as Howe, Sauveur, Stead, Heyn, and probably Osmond himself, are always careful to express their belief that it may be carbide and not carbon that is dissolved to form martensite and austenite, but exists all through from the cold condition to the fused, but not as the same carbide all through.

The free cementite carbide is Fe_3C, and the pearlite carbide is also Fe_3C, which is hard, but not hard enough to counteract the softness of the ferrite with which it is intimately associated in pearlite, and to give to the steel the general quality of hardness. But heat the steel, and at 710 deg. C. the affinity of the carbon for the iron becomes so greatly augmented that it is able to hold in combination 24 atoms of iron instead of only 3, so that at this temperature the hard Fe_3C of the pearlite takes up and combines chemically with the soft ferrite (iron) of the pearlite to form a new and intensely hard carbide $Fe_{24}C$, which Prof. Arnold calls hardenite, and which corresponds to the martensite of the allotropists. This carbide, being not only hard in itself, but also not being intimately mixed any longer with soft ferrite to form pearlite (the ferrite having been taken up and now forming part of the carbide) imparts to the steel itself the quality of hardness. If the steel be over 0.89 per cent carbon, or "supersaturated," or "hypereutectoid," and consequently contains no free ferrite but free cementite (hard) along with this very hard hardenite, then the steel itself is very hard indeed.

But the steel is not so hard, although still very hard, if it be unsaturated or "hypereutectoid," and contains at this stage ferrite along with the hardenite.

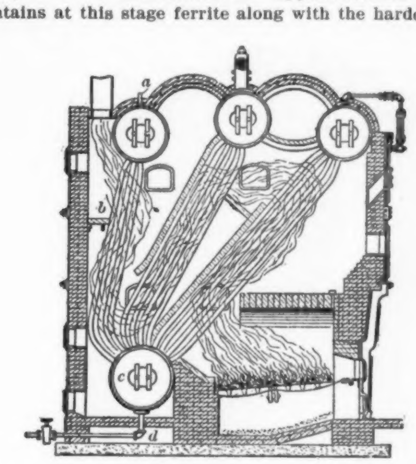


FIG. 10.—BLOW-OFF CONNECTION OF STIRLING BOILER.

Continue the heat now to 900 deg. C., and the cementite, if the steel be over 0.89 per cent carbon, or the ferrite, if it be under 0.89 per cent carbon, dissolves in the hardenite to form a homogeneous molecular mixture corresponding to the austenite of the allotropists, and in so doing modifies the extreme hardness of the hardenite so that the steel, while still hard, is not so hard as in the preceding condition.

Here it is interesting to note that if Prof. Arnold's theory be true gamma high carbon steel should be harder than gamma low carbon steel. For in the first case it is a solution of hard cementite in hardenite, while in the second it is a solution of soft ferrite in hardenite. This, if true, has an important bearing on high speed steel manufacture since Mr. Taylor has led the way in making these steels gamma. For in that case it is a mistake to adhere to a carbon percentage of 0.50 to 0.70 per cent, and the steels should be of as high carbon as possible to get the advantage of greater hardness. Mr. Taylor's reason for comparatively low carbon was originally to avoid brittleness and unforgeability. But when, in aiming at high speed, he increases his tungsten and chromium to such a point that the steel becomes gamma, these reasons no longer have application. For in that case the higher the carbon the more thoroughly gamma, and gamma steel is tough and not brittle. And again, gamma steel is forgeable, according to Mr. Taylor, who forges at a light yellow instead of a cherry red heat, which changes his martensitic steels to gamma or partly gamma. So it would seem

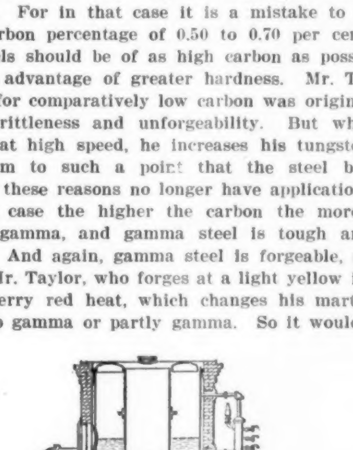


FIG. 11.—BLOW-OFF CONNECTION OF CAHALL BOILER.

that if we make a high-speed tool low-carbon gamma we get the quality of high speed or red hardness in the highest degree, but with the disadvantage of hardness not being what it might be, or what it ought to be, perhaps, for some work; whereas, if we make it high-carbon gamma, accepting Prof. Arnold's theory, we should expect to get a steel just as high speed and at the same time harder.

But it is not necessary for the practical man to consider whether the theory of Osmond or the theory of

* The Iron Age.

Arnold be true. All that is necessary to understand, at least in this connection, is that steel may exist in three conditions according to temperature: 1. Alpha or at first and for the most part pearlitic (soft), and at the end martensitic (very hard); 2. Beta or martensitic or hardenitic (very hard); 3. Gamma or austenitic (medium hard). The transformation points of these conditions are in unsaturated or hypereutectoid steels (steels under 0.89 per cent carbon) at these temperatures; from pearlitic (soft) to martensitic or hardenitic (very hard) at 710 deg. to 730 deg. C. (Ac_1); from alpha iron to beta iron at 730 deg. to 750 deg. C. (Ac_2), the steel in this beta range being still martensitic or very hard; from beta iron to gamma iron, and from martensitic (very hard) steel to austenitic (medium hard and tough) steel at 810 deg. to 830 deg. C. (Ac_3). In steels over 0.89 per cent carbon (supersaturated or hypereutectoid steels) these three transformation points, Ac_1, Ac_2, and Ac_3, merge into each other at 710 deg. C. to 730 deg. C.

Now introduce another metal—nickel, manganese, chromium, tungsten, molybdenum, but not vanadium—into the steel and two wonderful things happen. In the first place these transformation points are lowered, and in proportion to the amount of the added metal until when enough of the added metal is present, these transformation points are lowered below ordinary temperatures, so that the steel is martensitic or very hard without any quenching whatever. In other words, it is self-hardening, and if we go further and put still more of the added metal into the steel it becomes gamma or austenitic (medium hard and tough) at ordinary temperatures and without quenching.

But all the above-mentioned metals do not act in precisely the same way. Nickel and manganese are the only ones that are exactly as we have described. In the case of chromium the effect is to lower the transformation points, at least in presence of carbon, according to Dumas (but disputed by Prof. Carpenter, who declares the opposite), as we have described, and to make the steel martensitic or self-hard if enough be present, but if still more be then added, according to Dr. Guillet, the effect is not to put the steel in the gamma or austenitic condition, but instead a soft, brittle, double carbide of iron and chromium is formed. But if the steel be heated to a high heat (1,200 deg. C.) this double carbide is destroyed, and the chromium and carbon thus set free then act to put the steel in the gamma or austenitic condition, persisting at ordinary temperatures.

In the case of tungsten, and also of molybdenum, a soft, brittle, double carbide is formed as with chromium, but with this difference, that it is formed from the start when there is but little in the steel. There is no lowering of the transformation points, whether the tungsten or the molybdenum is low or is high, until the steel is heated to a very high temperature, when this double carbide is then destroyed, and the tungsten or the molybdenum is then free to work to lower the transformation points and to make the steel martensitic or self-hard, or to make it gamma or austenitic (medium hard and tough) if still more of the tungsten or of the molybdenum be present. In other words, tungsten and molybdenum steels are not self-hardening except they be heated almost to the melting point.

But here is to be noted a peculiarity. If nickel, chromium, or manganese be also present in the steel to a considerable amount, then, without any of this high heating, the nickel or the chromium or the manganese destroys a certain proportion of the tungsten double carbide, and the limited amount of tungsten thus set free then, of course, acts to assist the nickel, the chromium, or the manganese in making the steel self-hard. In other words, tungsten or molybdenum when alone in steel has no self-hardening effect (except at a heat of 1,200 deg. C.), but does have it to some extent in the presence of nickel, chromium, or manganese. In making clear this point Dr. Guillet has performed an important service. We see now that the old self-hardening steels were made under a very mistaken idea. Instead of tungsten being the self-hardening element, it was manganese and chromium that really did the work, with tungsten getting all the credit for it.

To repeat: Tungsten or molybdenum when alone in steel forms a soft, brittle, double carbide which must be destroyed by heating the steel to 1,200 deg. C. before the tungsten or molybdenum can work to lower the transformation points. But when nickel, chromium, or manganese is also present in considerable amount, this formation of double carbide is to some extent hindered or checked, and the tungsten or molybdenum then does, at once and without the heating to 1,200 deg. C., have some self-hardening effect.

Coming now to vanadium, Dr. Guillet finds that the double carbide also formed in this case cannot be destroyed at any heat, and vanadium therefore does not lower the transformation points of steel nor impart the temper resisting quality. In other words, it makes a steel neither self-hardening nor high speed.

Coming now to the second wonderful thing that happens when a second metal is made to alloy with iron in considerable proportion, alloy steels possess the property of resisting tempering or of retaining their hardness at a temperature much above that which will soften an ordinary carbon steel. This is a more wonderful and more valuable result than the lowering of the transformation points. But here it must be explained that this part of our theory is so far pure assumption only, and not yet confirmed by facts so far as we are aware. That other metals added to steel lower the transformation points of the steel is not theory; it is fact; it has been amply demonstrated. But that the temper-resisting quality is a part of the same phenomenon—that is, that every metal which lowers the transformation points of steel also and to the same degree makes the steel temper-resisting or high-speed—is as yet pure theory whose claim upon respectful consideration rests solely upon inherent probability.

Now with this theory before us what would we make the constitution of our high-speed mix, provided we knew nothing of all the practical work that has been done? In selecting a metal to put in our steel to make it high-speed, we would, of course, choose the cheapest metal that would do the work, and do it well. We would not select a metal that formed a soft, brittle double carbide which had to be destroyed by a very high heat (and then not completely) before the steel would harden or red-harden, and which at the same time was very expensive. We would first try a metal which did not form double carbide at all, and the cheapest metal that did not form double carbide. Manganese obviously would be the first metal we would try. The next question is, how much manganese? Obviously again, the greatest possible amount in order to get the greatest possible red-hardness; that is to say, enough to make the steel gamma at least. Then what carbon? Since we know that it requires much less manganese to bring a high-carbon steel to the gamma condition than it does to bring a low-carbon steel to that condition, for economy's sake we would make the carbon as high as possible, and undisturbed by any fear of brittleness because gamma steel is tough and not brittle. But yet we would move with some caution in this, because Dr. Guillet's experiments indicate that high-carbon gamma steels transform more readily by use into the martensitic or hard and brittle form.

The conclusion then that theory brings us to is that high-speed tools should be made from high-carbon Hadfield manganese steel. It is hardly necessary to state that this conclusion is entirely at variance with the universal practice. High-speed steel is neither made with manganese, nor is it made high carbon. That Hadfield manganese steel for some good practical reason will not serve we may be sure from the fact that it is not used. But it would be interesting to know what this reason is. Perhaps, after all, the difficulties connected with the use of manganese as a speed giver, instead of chromium and tungsten, whatever they are, are not insuperable. But assuming that they are insuperable, the question then is, why must both chromium and tungsten be used at the same time? If they are alike and equal in their action there is nothing to be gained by using them both at the same time, and if they are not alike, and one is better than the other, then there is something to be lost in using them both at the same time.

Referring to the work of Dr. Guillet and of Dr. Taylor for light on this point, we find that as a matter of fact chromium and tungsten are not alike and equal in their effects, chromium being evidently considerably superior. From the table of experiments given by Dr. Guillet on page 125 of the Journal of the Iron and Steel Institute for 1906, Vol. 2, where high-speed steels of varying composition are quenched at 850 deg. C., or not enough heat to completely destroy the double carbide, we see very plainly that high tungsten high speeds are much more difficult to harden (and to red-harden, according to the theory that red-hardness is a part of the same phenomenon as the lowering of the transformation points) than low tungsten high speeds, and still more difficult to harden than high chromium high speeds, provided the chromium is not high enough to form double carbide. Moreover, it would seem from his following table that when hardened at 1,200 deg. C. the high tungsten high speeds are not so hard (and presumably, therefore, not so red-hard) as these others. The reason must be that with much tungsten the soft, brittle double carbide is not destroyed entirely by the high heat given the steel for that purpose, and the higher the tungsten the greater the proportion of undestroyed double carbide.

But with chromium the case is entirely different, because no double carbide is formed at all, according to Dr. Guillet, until the chromium reaches 10 per cent in an 0.80 per cent carbon steel (or 15 per cent in 0.20 carbon steel), and the structure is not completely double carbide until 18 per cent chromium is reached; whereas, in tungsten steels the structure is completely double carbide after 4.5 per cent tungsten. So it is easy to understand why high tungsten high speeds are so much more difficult to harden than high chromium high speeds, provided the chromium is not high enough to form double carbide. It is the difficulty of destroying the double carbide, and from the evidence of Dr. Guillet's table of experiments the conclusion can hardly be avoided that, on account of this double carbide difficulty, tungsten in a high-speed steel is nothing more than an indifferent substitute for the right thing.

Turning now to Mr. Taylor's article for further information on this point, we find that our impression that tungsten is but a poor sort of a substitute is deepened and confirmed by his experiments. He finds that a mix of C 0.70-Cr_3-W_{18} gives a steel of a cutting speed of 60, or close to it. Increasing the tungsten in this mix he finds lessens the speed, while increasing the chromium to 5.5 per cent raises the speed to 99, and leaving out all the chromium deprives the steel entirely of all high-speed properties. Consulting now Prof. Carpenter, we find the statement that chromium is the main constituent in the high-speed mix. So on all sides we see evidence of the inferiority of tungsten as a speed giver; yet not one of these authorities even hints at such a thing as dispensing with it.

Let us see what their several objections to an all-chromium mix are, and consider whether these objections are valid. Mr. Taylor's objection is that chromium alone gives no high-speed properties. When he found that tungsten without chromium would not work (perhaps because he did not allow any longer time at the high heat) he promptly jumped to the conclusion, it seems, that the high-speed property came not from tungsten alone, not from chromium alone, but from the two together in steel. But we see that if he had had more patience and had tried chromium alone, he would have come to a different conclusion, for Dr. Guillet, who tried chromium alone (practically alone, $Cr_{10}W_2$) found that it made an excellent high-speed steel with this objection only, that it was martensitic or self-hard, and hence difficult to work. This is Dr. Guillet's objection to an all-chromium mix, that much chromium makes the steel self-hard and difficult to forge, or, if still more of it be used, it makes the steel gamma, or too soft, he thinks, for a high-speed tool.

It is interesting to note that this objection to chromium of Dr. Guillet is in flat contradiction to Prof. Carpenter's objection. The former objects to it because it does a certain thing, and the latter because it does not do that same thing. Dr. Guillet deprecates the use of much chromium because it lowers the transformation points and makes the steel martensitic or self-hard (and therefore difficult to work), or, if still more be used, it makes the steel gamma (and therefore too soft). Prof. Carpenter deprecates the use of much chromium because it does not lower the transformation points (and therefore has no high-speed or red-hardening effect). According to Prof. Carpenter, the function of chromium in the high-speed mix is simply and solely to destroy the tungsten double carbide (or cause complete solution of the elements, as he puts it). That chromium does do this we may readily concede. For we see that Dr. Guillet's experiments, even on ordinary self-hardening steels, indicate the same thing.

Tungsten, no matter in how large amount, does not make steel self-hard so long as it is alone in the steel, but when chromium or manganese is also present, then to a limited extent the tungsten is captured, so to speak, and dragged along and made to help the chromium or manganese make the steel self-hard. That is, a certain proportion of the tungsten double carbide is destroyed by the chromium or by the manganese. Then if we heat up to 1,200 deg. C., what more natural than that more, and much more, of the tungsten double carbide gets destroyed by the chromium? So we need have no hesitation in following Prof. Carpenter's theory so far. And if he is right also in his other point, that chromium itself has no high-speed effect, then, of course, the present high-speed mix is strictly logical: Tungsten to red-harden, chromium to make the tungsten available for that purpose by destroying or helping to destroy the tungsten double carbide, the tungsten and carbon thus released then hardening and red-hardening the steel.

But even so, the question must be asked, why use a metal which has to be driven to do its work by some other metal, and is at best never completely subdued? We see that there is a certain waste involved in the use of tungsten. The double carbide does not get entirely destroyed. Why not, then, use a metal which, like nickel or manganese, does not form double carbide at all, and which therefore would not require any chromium to get it to work? But we need not indulge in any rainbow chasing on this point. Both Taylor and Carpenter have promised us efforts to cheapen the high-speed mix, and if the result of these promises is that the latter announces that the present mix is about a finality, and the former has nothing more to say, then we may safely set it down as a fact that for some reason nickel and manganese will not do.

This brings us back to our question, what is the matter with an all-chromium mix? Is Prof. Carpenter right in his theory that chromium is not self-harden-

ing, and therefore not red-hardening? The evidence to the contrary, at least when carbon is present, is overwhelming, and, to top all, Dr. Guillet makes an actual trial of an all-chromium steel (practically all chromium, $C\,0.20\,Cr_{10}$-W_2), and finds it makes an excellent high-speed tool. So we can hardly believe that Prof. Carpenter's objection to an all-chromium mix is a valid one. Then there remains to be considered Dr. Guillet's objection that chromium in much quantity makes the steel martensitic or self-hard, and therefore hard to forge; or, if still more be used, it makes the steel gamma and therefore too soft.

According to Dr. Guillet, a high tungsten is the ideal high-speed mix for the very reason that tungsten forms a double carbide destroyed only with difficulty and by a great heat. This, he would claim, is tungsten's chief recommendation, and is something not to be complained about, but to be grateful for. It is a lucky dispensation of Providence, for it enables us to forge easily, using a low and careful heat, and then, when forging is done with, all we have to do is to heat up to 1,200 deg. C., and, presto! we get the hardness and the red-hardness. Whereas, if we use chromium altogether, it is true, he would say, that we would save considerable expense, and there would be less waste or no waste at all through failure of the double carbide to be completely destroyed, but of what use would this be to us if the steel was self-hard and unforgeable?

This objection is plainly a very important and weighty one, but when we turn to Mr. Taylor's work we find it is not an insuperable one. We see that Mr. Taylor runs into precisely this difficulty, the difficulty of self-hardness and unforgeability, when he raises the chromium in his mix from 2 to 3 per cent to 5.50 per cent (making it $C\,0.70{=}Cr\,5.5{=}W_{18}$), but we see further that it is a difficulty that does not daunt him, but that on the contrary he finds a way to get round it, and a very effective and ingenious way it is. Instead of forging at the usual low and careful heat, he boldly strikes out in the opposite direction and heats to a light yellow, whereby enough of the tungsten double carbide is destroyed, so that the steel is converted from the martensitic or difficultly forgeable condition to the gamma or easily forgeable condition.

But in putting enough chromium into his steel to make it gamma or partly gamma when finished, he of course runs into Dr. Guillet's second objection to chromium, that it makes the steel gamma, and therefore too soft if much be used. But this objection Dr. Taylor finds is not a good one. Gamma steel is not too soft. Since Dr. Guillet has become acquainted with Mr. Taylor's practical results, it is probable that he has entirely changed his opinion on this point. So that we see that Dr. Guillet's objection to an all-chromium mix would apply only if the carbon and chromium were high enough only to put the finished steel in the martensitic condition, and that this objection would not apply if these proportions were still higher, so that the steel finished in the gamma is in at least partly gamma condition. For gamma steel is not hard to forge, neither is it too soft for a high-speed tool, according to Mr. Taylor.

The end to be aimed at, then, in making an all-chromium mix is to make the steel gamma or partly so, not only to avoid the difficulty of forging, but also to get the advantage of higher speed combined with toughness, an advantage which Mr. Taylor has gained in his latest mix. But in doing this we get into the same disadvantage, although to a less degree, that attaches to the use of tungsten, and that disadvantage is the double carbide which forms when we put enough chromium into the steel to make it gamma, and which can only be destroyed at a heat of 1,200 deg. C. So although chromium is better to use than tungsten, because the structure is not entirely double carbide until 18 per cent is used in an 0.80 carbon steel, whereas with tungsten it is entirely double carbide at 4.5 per cent, and because the double carbide is more easily destroyed, yet it would seem obvious that it would be better still to use a metal which, like nickel or like manganese, formed no double carbide at all, provided of course, such a metal had no defects of its own in other respects.

As before stated, that there are such defects we may infer from the fact that these other metals are not used. In the case of nickel, indeed, there is one defect that is obvious—the large amount of it needed to make the steel reliably and permanently gamma. But this defect does not attach to manganese, which moreover, has the great advantage of cheapness. Theoretically it is hard to guess why Hadfield manganese steel does not serve, although, of course, it is plain that its difficulty of being machined would bar it from some uses.

A mix that theoretically would seem to be an advantageous one would be chromium in amount just short of enough to form the double carbide (the double carbide begins to form after 10 per cent chromium in an 0.80 carbon steel, according to Dr. Guillet), with enough manganese then added (perhaps 3 per cent), so that the sum of the chromium, manganese, and carbon is high enough to make the steel gamma.

As before stated with regard to carbon, theory indicates that carbon should be high, as, according to Dr. Guillet, the higher the carbon the less tungsten and chromium would be required to give the same high speed effects. Mr. Taylor, on the contrary, states emphatically that carbon has nothing whatever to do with it. "Experiments indicated that as far as the effect of cutting speed is concerned, it was a matter of indifference whether low or high carbon was used," he says, the three experiments in his tables bearing on the point confirming entirely his statement. But yet we cannot be entirely satisfied that he is right and Dr. Guillet wrong. We think that in these experiments it has happened that the heat treatment has nullified the carbon; that is, it has happened that in all these three experiments less of the double carbide was destroyed than usual.

That carbon has no influence on cutting speed, other things being equal, is hard to believe. The fact that a high-carbon steel is more susceptible to any influence, good or bad (thus, for instance, a high-carbon steel will self-harden when a low-carbon steel will not), than a low-carbon steel is a fact so well established and so familiar to every practical man that we find it hard to believe that here, in the matter of red-hardness, nature has reversed her laws. Moreover, as Mr. Taylor is careful to point out, the experiments he makes show that in this matter of red-hardness there is some other factor than chemical composition. The same mix gives sometimes different results, and different mixes sometimes the same results.

Thus, for instance, we see chromium reduced one-half, the mix otherwise remaining the same, and yet the cutting speed not altered a particle. Now, if we would deduce from this that chromium had no high-speed effect, and that it was a matter of indifference whether the chromium was low or high, we would of course be greatly in error. So, too, we might be in error in deducing from his experiments that the percentage of carbon was a matter of indifference. There is some other factor than chemical composition, and a factor so important that it at times completely masks the effect of chemical composition.

That factor is the heat treatment, or, in other words, the destruction of the double carbide. That is, if a high-speed steel of the right composition gives poor results, or if the wrong composition gives good results, it is because the heat in the one case has not been, and in the other case has been, high enough or long enough continued to destroy completely the double carbide. Dr. Guillet always uses the word "dissolve" to describe this phenomenon. But to us it seems that the idea of complete destruction, and not simple solution, is more expressive of the facts. The simpler and better to be understood theory is the theory that the carbon cannot harden (that is, go into the hardenite combination), and the tungsten cannot act to lower the transformation points and to give the temper-resisting quality, so long as they are locked up in this soft, brittle double carbide combination. That this combination must be actually destroyed and not merely dissolved, it is reasonable to suppose. Mr. Taylor's own theory for the unknown factor is that it is oxide in the steel and that vanadium takes it out.

So, although it is quite true that three of Mr. Taylor's experiments bear out the idea that the percentage of carbon has no influence on the cutting speed, and none of his experiments show the reverse of this, still, in view of the obvious improbability of this idea (high-carbon steels in general being so much more sensitive to all influences than low-carbon steels), in view also of Dr. Guillet's opinion to the contrary of this idea, and his experiments to the contrary, we cannot yet feel convinced that Mr. Taylor is right on this point, and we have to think that high-speed steel should be high carbon in order to get the greatest high-speed effect with the least expenditure of added metal.

In one point practice and theory coincide. Theory indicates that the high-speed tool should be gamma steel, even although some hardness is thereby sacrificed. Probably the great majority of steelmakers have not yet followed Mr. Taylor in this point, but undoubtedly will do so eventually.

To sum up: The high-speed mix which the steel trade has arrived at by practical trial and experiment is not the mix that the theorist would deduce from theoretical considerations as well as from the practical experiments of others. Instead of high tungsten and comparatively low carbon, the theorist would make it high carbon, and tungsten would be the last metal he would use, on account of the double carbide difficulty and waste. There can be no doubt that manganese has been given a trial by the practical experimenters, who, however, have not described their results with it, so that we can only guess at the reason why this metal does not serve. With regard to chromium, however, we are not in the dark in this respect. The objections to it are very explicitly stated. Not forming double carbide at all under 10 per cent in an 0.80 carbon steel, but acting at once to lower the transformation points, the steel is martensitic or self-hard, and therefore hard to forge, when, on the contrary, the tungsten high speed is double carbide and therefore easy to forge. Then, if we go further and put enough chromium in the steel to make it also an entirely double carbide (18 per cent in an 0.80 carbon steel) it then is forgeable, probably like the double carbide tungsten steels, but after the double carbide is destroyed by the 1,200 deg. C. heat, this high percentage of chromium makes the steel gamma or too soft for a high-speed tool, it is claimed. These objections to chromium have been entirely swept away by Mr. Taylor. Gamma steel he finds is not too soft. Still, he tenaciously holds onto tungsten because of his belief that the red-hardness comes not from tungsten alone, nor from chromium alone, but from the two together in steel.

GLASS MAKING BY MACHINERY.*

By GEORGE A. MACBETH.

THE press might be said to be the first machine of consequence in regard to forming glass by machinery, and its use in this country has been very extensive, the best process and the best work being done here. Within the last ten or fifteen years blowing glass by machinery has arisen and it is now an important element in the manufacture, fairly revolutionizing the process.

The paste mold has been well known and accomplishes what we can hardly accomplish in other directions, but it took quite skilled labor to do it well. So it led finally to the invention of what we know as the Owen's blowing machine; the general principle of which is five paste molds carried on a circular strap at least three-fourths of the circle. Then it comes to an incline and drops in water, for the purpose of cooling the molds. Compressed air does the blowing, and whereas formerly we would pay a gatherer of glass for *gathering and blocking*, as it is called (putting it in form to be introduced into the mold), as well as the blower, with the machine the blower, in place of doing any blowing, just places the pipe in the machine perpendicularly, gives the merest little puff of air, and his work is done. And it is better done than any human being can do it, because it is self-centering and we can blow articles of considerable length, 12 to 14 inches, with almost absolutely uniform walls and sides. Hardly any of it is thick on one side and thin on the other. They are so uniform that I would be willing to take a contract for 100,000 on a stipulation that they would not vary over 1/32 inch in diameter, 10 to 14 inches long.

I want to speak of one more machine, about which I do not know quite as much, having merely examined its operation; that is, the Owen's bottle machine. It is entirely automatic, being a combination of pressing and blowing. It requires no glass blower at all. A man with an oil can and a monkey wrench can do all the work. It is fitted with five molds, and just as they get over where the glass is, in their revolution, the receptacle gives a little curtesy and dips out just as much glass as needed. In that way it will turn out sixteen beer bottles in a minute and work Saturdays and Sundays and holidays and all the time.

Glass under pressure, like a locomotive boiler, with 200 to 250 pounds pressure, and hot water and steam, is soluble. If you put a pop bottle in such a boiler it will dissolve. It is really more soluble in cold water than one would think, for distilled water, pure water, attacks some glass as much as a strong alkali or an acid, and it shows in delicate tests for alkali. In glass that has to stand a pressure of 250 pounds and hot water, that is quite a problem. Even rock crystal can be fused. And what that means one may guess when it is considered that sand that has been at a temperature of 2,800 deg. for two years without cessation, is microscopically no different from sand that was never used at all. The angles were just as sharp. From this one can tell the difficulty of melting sand or rock crystal. We *can* melt it, but what is to be done when melted? It cools so quickly that it is difficult to get it in any form at all. The expense is very great and to get it into some forms is all but impossible. Then the necessary temperature of 4,000 deg. or over is apt to destroy the containing vessel and lose hours of melting. This is rather a hazardous undertaking and the results are erratic, so that glass of that kind is necessarily expensive.

There is such a thing as case-hardened glass; a piece of glass heated to low redness, dropped in tallow at about 320 deg. F. comes out case-hardened. Through the polariscope it will show all the colors of the spectrum, but just as soon as the case-hardened surface is cut through it flies into a thousand pieces in all directions. The strain overcomes the tensile strength of the glass and an explosion is the end of it. It does very well in some things, but not in others.

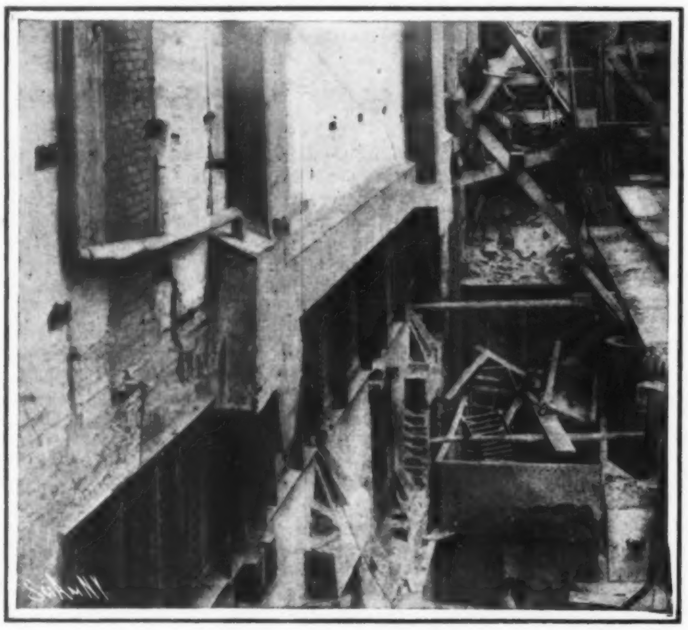
* Abstracted from a paper read before the Engineers' Society of Western Pennsylvania.

CAISSON FOUNDATIONS OF SKYSCRAPERS.*

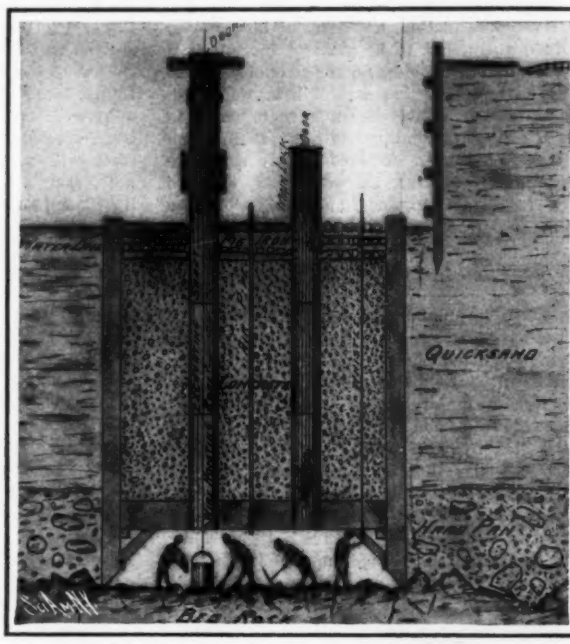
SAND HOGS AND THE WORK THEY DO.

BY T. KENNARD THOMSON, M. AM. SOC. C. E.

In skyscraper work the sand hog is used to place the caissons employed in the foundations. A caisson may be described as a box with four sides and a roof, but no bottom, the lower part of the sides being called the "cutting edge," as they are supposed to penetrate into the ground as the sand hogs excavate the material. In the roof are one or more holes, generally three feet in diameter, over which are bolted steel shafts three feet in diameter and long enough to extend some distance above the top of the ground, and on top of these shafts is placed the air lock, a steel chamber with two doors, one above the other, the object of the air lock being to prevent all the air in the air chamber escaping when the bucket or men enter or leave the air chamber.



UNDERPINNING AN 18-STORY WALL. THE WEIGHT WAS TRANSFERRED TO THE GIRDERS SHOWN WITHOUT A TREMOR.



THE CAISSON SUNK TO THE BED-ROCK FOUNDATION.

The air lock acts like a double porch, so that by entering the lock and closing the top door before opening the lower door only that amount of air between the two doors is lost each time man or material enters or leaves the caisson. When the work under the caisson is finished it is left in place filled with concrete and becomes a part of the foundation.

The method of holding the door shut is absolutely safe and simplicity itself, for the doors always should open inward, so when a man enters the lock at atmospheric pressure the lock tender pulls or forces the door up against its frame and the compressed air is allowed to enter the lock, gradually, of course, and at once acts against the door to keep it shut, the pressure being from, say, two to forty-five pounds per square inch. As soon as the air pressure in the lock equals that in the shaft and air chamber below, the pressure on the top and bottom of the lower door is equal and the weight of the door itself causes it to fall open.

To give an idea of the immensity of this pressure, most caissons in lower New York require at least 20 pounds a square inch before they are landed. Some require 45 pounds (about the limit of human endurance) a square inch in addition to atmospheric pressure. Now, a three-foot opening in a shaft equals about seven square feet, or 1,018 square inches, and 20 pounds a square inch on this area would equal 20,360 pounds, or more than ten tons, and if the pressure were 40 pounds a square inch it would take twenty tons pressure to force the door open.

Caisson men always disregard atmospheric pressure, which is between 14 and 15 pounds a square inch, when talking about air pressure.

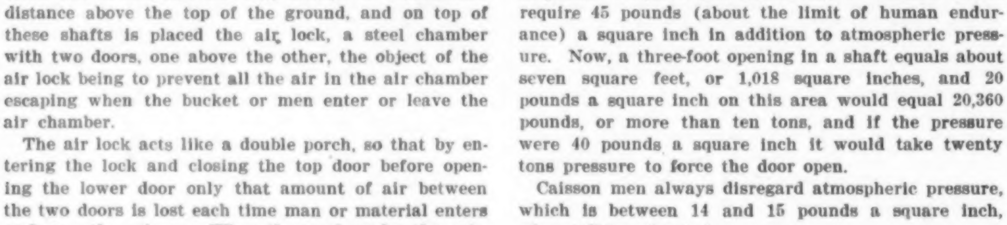
I once asked a school girl who wanted to know something about air where a man could do the most work, on top of a mountain, where the atmospheric pressure is much less than here below, or down in a caisson, where the pressure is from 20 to 40 pounds on every square inch of surface of the body. At first she said: "Up in the light atmosphere," but quickly corrected herself and said: "In the caisson, of course, because one breathes so much more oxygen there that it gives one more energy," which is a fact that probably very few sand hogs have ever reasoned out.

They all know, of course, that everything burns up quickly in the air chamber. In fact, I have seen more than an inch of a cigar red while being smoked and a candle blown out and put in a workman's pocket only to set the coat on fire in a few minutes. Many a time in looking for leaks to see where the air is escaping the flame of a candle catches the oakum or woodwork and a fire is started that is exceedingly hard to put out.

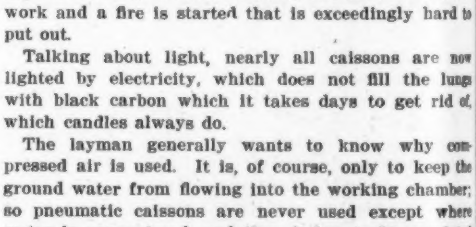
Talking about light, nearly all caissons are now lighted by electricity, which does not fill the lungs with black carbon which it takes days to get rid of, which candles always do.

The layman generally wants to know why compressed air is used. It is, of course, only to keep the ground water from flowing into the working chamber; so pneumatic caissons are never used except where water is encountered, and then it has to be regulated so as to exactly balance the water pressure, which we know, of course, always depends on the depth. For instance, a cubic foot of water weighs 62½ pounds, which is equivalent to 0.434, or nearly one-half a pound on every square inch of the bottom, so a column of water 10 feet high would weigh ten times as much, or 4.34 pounds a square inch, and at 100 feet down, the pressure would be 43.4 pounds, which is as much as can be borne.

* From the New York Herald.



SAND HOGS DESCENDING TO WORK; THEY GO DOWN SMILING AND RETURN LOOKING TIRED.



SINKING A CAISSON THROUGH QUICKSAND.

THE CAISSON FOUNDATIONS OF SKYSCRAPERS

If the air pressure is too little the water rushes in, bringing sand and mud with it, which would drown the sand hogs unless they could get out quick enough and leave a cavity outside for the adjoining building to fall into, and if the air pressure were too great, a blowout would occur with equally serious results, for the air pressure would thus be reduced, allowing the water and earth to rush in.

In fact, sand hogs have to be on the alert all the time to avoid just such accidents, which frequently happen in spite of them, with more or less serious results.

Many other causes of accident exist which often tax even the nerves of old-timers, especially when something happens to the lock and men are compelled to stay in the caisson ten to twenty hours extra, burning up their energies without even food to partly restore the same. A sand hog will, due to the plentiful supply of oxygen, do far more work in the air chamber than on the surface, with the result that he eats heartily, and one seldom sees a thin sandhog, but he must burn up his vitality, for there are very few old sand hogs.

It is a peculiar fact that even the best of caisson men can rarely earn their salt on outside work, although they will accomplish wonders down below and are withal the worst paid of any union, the reason being that, with the exception of the foremen, no particular training is required; for if the man has good nerves and muscles the foreman can break him in in a day. Irishmen and Swedes make the best material. I have also had some splendid negroes, but some engineers have had negroes in the South stampede in the case of an emergency and have been afraid to use them after.

Sand hogs now get $3.50 a day of eight hours, with one-half hour off for lunch, when working in pressure up to 20 pounds a square inch, above which the wages increase rapidly and the hours of labor decrease until the limit is reached at 45 pounds, where the men are allowed to work only one and one-half hours a day, and even that is divided into two three-quarter of an hour shifts, with a rest of four hours between, and even then many are overcome by caisson disease, commonly called the "bends." Many cannot even stand light pressures and none are allowed in the higher pressures without a medical examination, for we know that if there is anything wrong with the heart or lungs it is suicidal to try to enter the lock. In fact, one must be in absolutely perfect condition, and even then not attempt to enter on an empty stomach, which has been the cause of more than one sand hog being paralyzed.

The first effect generally noticed when the air is let into the lock is the pressure of the air on the ear drums, and if this pressure is not quickly equalized the ear drum is ruptured—of course, for life. At other times this "plugged" sensation results in blood vessels being ruptured in the head, which danger is much greater if the person has a cold. In fact, if he has a cold or anything at all wrong with his heart or lungs he has no business to enter at all. Even men in apparently perfect physical condition cannot always endure the pressure. When the compressed air is allowed to enter the lock too quickly, and sometimes even when considerable time has been taken in entering and leaving the lock, the air bubbles force the blood away from the surface, and then, when coming out of the compression, many of the bubbles remain in the system, which results in the "bends." The attack is usually in the arms or legs, though occasionally in the body. The longer one stays in compressed air and the more exertion taken in it, the greater the risk of "bends," which, however, often do not make themselves felt for several hours after coming out, although some sand hogs say they can feel the symptoms while still in the air chamber.

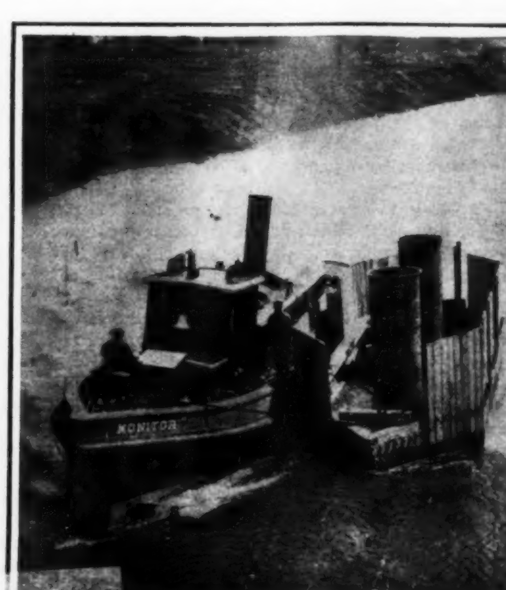
THE TRINITY AND UNITED STATES REALTY BUILDINGS, NEW YORK, ARE BUILT ON CAISSONS WHICH WERE PREPARED IN RECORD TIME.

The worst form of caisson disease is paralysis, from which some die at once, some recover, and others are afflicted for the rest of their lives, and which it will be none can tell. Many of the old watchmen on big contracts are such victims.

The French have made many experiments and have found that by letting a man lie on a couch in a glass air chamber and taking a long time to raise and lower the pressure 90 pounds a square inch in addition to atmospheric pressure can be safely withstood, and it is recommended that the workman take 20 minutes for each 15 pounds of pressure to enter and leave the lock. Thus if the pressure were 45 pounds, it would take an hour to enter and an hour to leave the lock. But it would be very hard to enforce this rule in this country, and the sand hogs themselves would object the most. In fact, they are such reckless fellows that whenever they get a chance they open up the valve full to get in or out as quickly as possible, and they will even come out of the hot caisson on a cold winter's day with nothing on but their thin overalls, with all the chest exposed. Is it any wonder they die young?

The act of compression also heats the air so that in summer, especially, it is necessary to cool it with

CAISSON WORK ON THE TRINITY AND UNITED STATES REALTY BUILDINGS SITE.



TOWING A CAISSON TO ITS POSITION FOR AN UNDERWATER FOUNDATION.

THE CAISSON FOUNDATIONS OF SKYSCRAPERS.

water pipes or ice before allowing it in the caisson. When the cooling apparatus has temporarily broken down I have seen the thermometer rise to 106 deg., and even higher, when the men cannot or will not work until it is remedied.

On the other hand, if one takes good care of himself he can stand a good deal. I have been at work in emergency cases for eighty-six hours (Monday morning to Thursday night) at a stretch repeatedly, going in and out, but not staying in for any length of time, without experiencing any ill effects, but have no desire to repeat the experience.

It is only fourteen years since pneumatic caissons appeared for building foundations, and it is only lately that the necessity for them is being appreciated. Even Chicago is coming to this view, after building on "spread" foundations for years and having the buildings settling continually, some as much as two feet. Some used to insist on wooden pile foundations because they were cheap, but we can never be sure that the piles are driven to hard ground, and we know for a fact that they very seldom are. I have removed piles which were guaranteed to rest on bed rock and found there was not a pile in the lot within twenty feet of the rock. I have removed what first looked like a good pile to find that while it was twelve inches in diameter it was nothing more than a block eight inches deep buried in concrete. Wood, if kept all the time under pure water, will last for centuries, but if alternately wet and dry it will last only a short time, and we know that tunnel and other operations are constantly drawing the water from the pile foundation. This sooner or later will allow a building to settle.

Now, it is a question whether the owner is willing to pay for the extra cellars. Many think New York's substrata will sooner or later be overloaded and allow the island to sink, and it seems difficult to realize that a load of fifteen tons a square foot under a thirty-story building does not cause any greater weight a square foot than fifteen tons a square foot under a three-story building. In other words, the building laws do not allow a greater load on concrete foundation than fifteen tons a square foot, and the only difference is that the foundations for the big building must necessarily cover more square feet. This is equivalent to about two hundred pounds a square inch, and it is poor wood, hardpan, or rock that will not sustain safely two hundred pounds when resting on a block one inch square.

Let a woman weighing one hundred pounds stand on a block one-half an inch wide and an inch long and she makes as great a load a square inch as will ever be placed by the highest of buildings, and even if she places the block on good sand or hard earth she will not force it very far into the ground.

Under the New York quicksand, which is from thirty to sixty feet thick, we find from two to thirty feet of hardpan. Sometimes this is directly on the rock and sometimes we find masses of sand and bowlders under the hardpan. Good hardpan, if on bedrock, will hold up any building that will ever be raised in New York, but nothing except personal examination of each individual caisson foundation on the job is sufficient to decide whether the hardpan is really good, and even then it is necessary to determine if the good hardpan extends to the rock or not. This opinion is the result of having been down in the air chamber more than two thousand times.

The deepest caisson foundation in New York is under the Mutual Life Building, where the depth is 100 feet below the curb and 85 feet below the surface water, through 30 feet of quicksand, 23 feet of hardpan, and then 32 feet of sand, bowlders, and decomposed rock, which we took out with a shovel. Its color made some of the men think they had struck a vein of gold, but, alas! the hope was vain.

Of course, the introduction of pneumatic foundations necessitated a much higher grade of contractors than an ordinary cellar digger and also made more work for engineers, for much ingenuity and eternal vigilance are necessary to prevent loss of life and property. Many buildings have been so damaged that they were barely saved from ruin. One building, some twenty stories high and not completed, was so undermined by an adjoining excavation (they tried to save money by not using pneumatic caissons) that the building was thrown 18 inches or so out of plumb, and the contractor was compelled, after the terra cotta floors had all been taken out, to employ competent iron contractors to "jack" the building back into its original position.

In the time of four-story buildings caissons were out of the question, as they would have cost much more than the building itself, and even when skyscrapers appeared it was hard to educate the public up to the fact that the quicksand which overlies the hardpan and rock in all the lower part of New York city was not a safe material on which to found a building. While it might be safe, after more or less settlement, if it were so confined that it had no opportunity of escaping, there is no place in lower New York where it is not likely to be tapped sooner or later by the foundations for another building or the excavation for a tunnel, and as tunnels from Jersey to Brooklyn will have to go below the Rapid Transit tunnel they are apt to undermine the lower strata of quicksand.

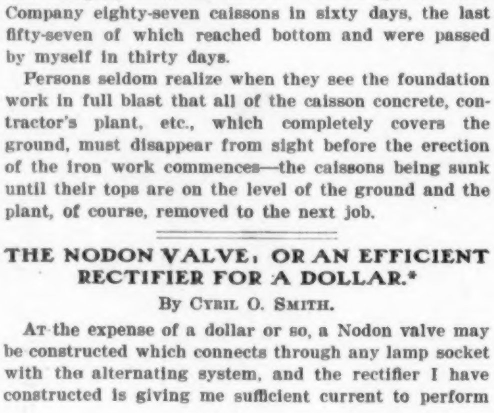
In early days a serious objection made to the use of caisson foundations was the length of time required. Then a contractor would only have one or two expensive locks and, consequently, only have one or two caissons going at a time, with often frequent waits in between. But now we have as many as fifteen locks in operation at a single site and perhaps twenty or thirty or more caissons in various stages of construction in advance of the air work, with the result that more work is now done in a month than used to be done in a year, and the cost to the owner is also very much less. The record so far was made on the Trinity and United States Realty Buildings, where the Foundation Company sank and filled for the George A. Fuller Company eighty-seven caissons in sixty days, the last fifty-seven of which reached bottom and were passed by myself in thirty days.

Persons seldom realize when they see the foundation work in full blast that all of the caisson concrete, contractor's plant, etc., which completely covers the ground, must disappear from sight before the erection of the iron work commences—the caissons being sunk until their tops are on the level of the ground and the plant, of course, removed to the next job.

THE NODON VALVE; OR AN EFFICIENT RECTIFIER FOR A DOLLAR.*

By CYRIL O. SMITH.

At the expense of a dollar or so, a Nodon valve may be constructed which connects through any lamp socket with the alternating system, and the rectifier I have constructed is giving me sufficient current to perform



experiments in electrolysis, work a couple of small motors, run a Ruhmkorff coil for wireless demonstration work and charge a storage battery, and not only doing this, but ready to do a great deal more, as occasion requires.

All that is required is four heavy battery jars, some heavy sheet lead, some sheet aluminium, eight binding posts, a few lamps of different candle-powers of the voltage of the alternating system and a saturated solution of ammonium phosphate in distilled water.

Cut out four sheets each of lead and aluminium of a size to fit comfortably in your battery jars, fasten a binding post to each sheet, and place in the battery jars already filled with the saturated solution of phosphate of ammonia, and connect up as in the diagram.

Heavy lines represent lead plates, light lines aluminium plates. Alternating-current mains are connected at *M*, lamp resistance is placed at either R^1 or R^2, and rectified current is taken off at $C-$ and $C+$.

If you can control your alternating current by means of a good lamp board, you will be delighted with the flexibility of the rectified current, but such a board is by no means a necessity, as for most light work a lamp of 100 candle-power, a 50, a 32, and a 16 will be all that are required. My coil for wireless work is operated with a so-called 100-candle-power stereopticon lamp and an ordinary 32-candle-power lamp in multiple, and runs with such freedom from trouble that the mere thought of a return to primary batteries is decidedly distasteful.

The following precautions are necessary to insure success:

1. Use distilled water if possible. If not, use very carefully collected rain water. Tap water will not do at all.

2. Add distilled water when necessary to take place of that evaporated.

3. Give both lead and aluminium plates a good scraping once in a while, and be sure and have them quite clean before starting up the first time.

4. Have everything set up over night, as rectification seems to start up more easily after plates have been in the ammonium phosphate solution some hours.

5. If too much foaming takes place with the particular load you are carrying, use larger jars and larger plates.

* Abstracted from School Science and Mathematics.

NEW EIFFEL TOWER WIRELESS PLANT.

THE Municipal Council of Paris has lately decided to install a radio-telegraph station at the Eiffel Tower which will be in keeping with its proportions, and will give it a rank among the great stations of Europe. Heretofore the power of the apparatus has been quite limited and the present plant was only a provisory one. Notwithstanding its very small power, the tower was able to send signals to a great distance, having kept up connection with Casablanca in Morocco during the recent troubles in that region. It could also send signals as far as Bizerta and Tunis, as well as to all the French coast stations. Not long since a commission of delegates from the Municipal Council made an official visit to the tower plant in order to come to a final decision in the matter. The points which were to be considered were the location of the post containing the apparatus and also the dispositions to be taken for placing the mast wires which are to hang down from the tower. These questions needed to be considered from the triple standpoint of financial interests of the city, public tranquillity, and esthetics. The delegates had all these matters explained by Commandants Devisme and Chasles, of the military radio-telegraph corps, and in order to have a better idea of the effect, a part of the mast wires had been put in place. As a result, it was decided to proceed with the construction of the new plant, without modifying the plans which the corps had drawn up, under the general direction of Capt. Ferrié. The laboratory or radio-telegraph post proper, which will contain all the needed instruments, storage batteries, etc., will be placed underground and below the park which now surrounds the tower. This will consist of a great chamber vaulted with masonry. It is found that the underground arrangement gives many advantages for such a post. It will be remembered that the working of the apparatus is accompanied by explosive sparks which with powerful apparatus come near the noise of a pistol shot. In the present plant, which consists of planked sheds on a level with the ground, the noise of the sparks can be heard for a great distance, and even as far as the other bank of the Seine. This is not only a disturbance for the residences adjoining the tower, but at the same time it allows of any one receiving the messages by ear. In time of war this would be a grave disadvantage. However, the underground plant will suppress the sound, and there will be no trouble from this reason. As regards the disposition of the mast wires, it will be carried out along well-studied plans and after the experiments made with the present wire. The network which will hang down from the tower will consist of four main wires stretched from the summit to the ground and having a maximum spread on each side of the tower of about thirty degrees. To the main wires will be attached a set of cross wires which will form a suitable network. The cross wires, however, will not be brought down to the ground, and here there will be but the four main wires, anchored in suitable pillars, which will in turn be fenced around so as to prevent any possible contact by the public. The importance of the new Eiffel Tower station cannot be overestimated. It is premature at the present time to say what distances can be covered by it, but there is no doubt that the completion of the post will mark a step in advance in the field of radio-telegraphy. Owing to the great height of the tower, we may see some surprising results.

The uses to which electrical machinery has been put in dock workings are numerous and are continually extending. For the loading of general merchandise the high gantry crane is much used, for short-distance electric traction capstans are very much in evidence, and for coaling vessels electric cranes and hoists are used, the former where the better facilities afforded by jetties or staiths cannot be arranged. Electric power is used also for preventing the breakage of coal which takes place when run from considerable heights into the holds of vessels, and it has recently been used to obviate in a simple and inexpensive manner the necessity for alterations to existing staiths and jetties, which the increasing size of ships employed in the coal trade would otherwise involve. In other cases it is found that, while not desirable to replace all hydraulic by electric plant, it was advisable to make a beginning on a settled policy. Such a case may be instanced as that at the North-Eastern Railway Company's Dock—Tyne Dock—where the steam pumping plant, being old, is being replaced by electrically driven pumps with the intention of gradually replacing the hydraulic cranes, etc., as necessity arises, by electric plant also.

THE SETTING OF PORTLAND CEMENT.

THE AMOUNT OF WATER REQUIRED.

BY C. K. FRANCIS.

VARIOUS methods have been proposed for determining the amount of water required to produce the setting of Portland cement, but none of them has proved entirely satisfactory.* The quantity of water which should be added to the cement must be determined by trial in each case,† as it will vary according to age, method of manufacture, etc. For neat cement, it is usually considered to be about 20 per cent, yet in rare cases it may run as low as 10 per cent and, at the other extreme, 27 to 30 per cent. For the regular three part sand to one cement mixture, the amount should be about 10 per cent; the extremes, 8 and 12 per cent. In testing cements, these amounts have been sufficient, but it is customary on construction works to add an excess.

An effort has been made to devise a formula in order to determine the percentage of water needed for mortars, and, although much study has been given to the subject, the problem is so complicated that not one has been recommended.‡ Zulkowski has prepared a number of synthetic cements§ and determined the water of hydration. The following calculations are based on his theories, considering a cement of the following composition as a type:

	Per cent.
Silica (SiO_2)	23.40
Alumina (Al_2O_3)	6.07
Ferric oxide (Fe_2O_3)	2.51
Lime (CaO)	63.87
Magnesia (MgO)	0.97
Potash (K_2O)	0.80
Soda (Na_2O)	1.22
Sulphur trioxide (SO_3)	1.45

—which was a cement of excellent quality.

By calculation, according to Zulkowski's views, this cement contains:

61.89 per cent.........dicalcium meta-silicate.
12.14 per cent.........dicalcium aluminate.
4.35 per cent.........dicalcium ferrate.
14.22 per cent.........calcium oxide.
0.97 per cent.........magnesium oxide.

The dicalcium meta-silicate requires one molecule of water for hydration; in the reaction, half of the calcium forms calcium hydrate, the silica remaining as mono-calcium silicate.

$$2CaO \cdot SiO_2 2 + H_2O = 190 \qquad H_2O = 18$$
$$SiO_2 = 60$$
$$H_2O = 18 \qquad 2CaO = 112$$
$$\overline{190}$$

$\dfrac{18 \times 100}{190} = 9.47$ per cent water required for dicalcium silicate.

In the above cement there is 61.89 per cent dicalcium meta-silicate.

$\dfrac{61.89 \times 9.47}{100} = 5.86$ per cent water required for that amount.

The dicalcium aluminate needs five molecules of water.

$$2CaO \cdot Al_2O_3 5H_2O = 304$$
$$5H_2O = 90$$

$\dfrac{90 \times 100}{304} = 29.6$ per cent water required for dicalcium aluminate.

In the above cement there is 12.14 per cent dicalcium aluminate.

$\dfrac{12.14 \times 29.6}{100} = 3.60$ per cent water required for that amount.

The dicalcium ferrate needs five molecules of water.

$$2CaO \cdot Fe_2O_3 \cdot 5H_2O = 362$$
$$5H_2O = 90$$

$\dfrac{90 \times 100}{362} = 24.91$ per cent water required for diferrate.

There is 43.5 per cent dicalcium ferrate present.

$\dfrac{4.35 \times 24.91}{100} = 1.08$ per cent water required for that amount.

Calcium oxide (CaO) needs one molecule water to form the hydrate:

$$CaO = 56$$
$$H_2O = 18$$
$$\overline{74}$$

$\dfrac{18 \times 100}{74} = 24.3$ per cent water required for lime (CaO).

There is 14.22 per cent lime (CaO) present.

$\dfrac{14.22 \times 24.3}{100} = 3.45$ per cent water required for that amount.

Magnesium oxide will combine with one molecule of water:

$$MgO = 40$$
$$H_2O = 18$$
$$\overline{58}$$

$\dfrac{18 \times 100}{58} = 31.01$ per cent water required for magnesia (MgO).

There is 0.97 per cent of magnesium oxide present in the cement.

$\dfrac{0.97 \times 31.01}{100} = 0.30$ per cent water required for that amount.

	Per cent water.
61.89 per cent dicalcium meta-silicate requires	5.86
12.14 per cent dicalcium aluminate requires	3.60
4.35 per cent dicalcium ferrate requires	1.08
14.22 per cent calcium oxide requires	3.45
0.97 per cent magnesium oxide requires	0.30
Total	14.29

Accordingly, 14.29 per cent of water will be required for the hydration of the above cement.

The above results were obtained by direct calculation, as indicated. Zulkowski has derived his result from the molecular formula, and obtained 14.67 per cent as the amount of water necessary for hydration.

Carbon dioxide and water are present in all Portland cements; freshly-ground cements usually show less than 1 per cent of these two constituents combined, while well-seasoned ones may show as much as 3 or 4 per cent.*

Several methods are used for analyzing the set cement for water.† In all of them the water is driven off at a high temperature, a red heat often being required, and the loss in weight of the cement will represent carbon dioxide and water. The amount of carbon dioxide may be found by analysis, then the difference will be water, or both may be determined quantitatively.

* "Standard Methods of Testing and Specifications for Cement." Edited by American Society Testing Materials, 1905, p. 13, sec. 28.
† Ibid., p. 14, sec. 28.
‡ Ibid., p. 15, sec. 28.
§ Zur Erhartungstheorie der hydraulicaen Bindemittel. Die Chemische Industrie, 1901.

* Mead, R. K., Portland Cement, 1905, p. 31.
† Ibid., p. 208.

FERMENTATION IN THE LIGHT OF MODERN SCIENCE.

IN the beginning of the last century it was not known that yeast is a living agency. The nitrogenous nature of the yeast substance, however, was known, and it was the general opinion that the albuminoids of the fermentation media, in combination with the atmospheric air, underwent a decomposition, in which the yeast was separated. Gay-Lussac was probably one of the first who succeeded in bringing about the preservation of foodstuffs by the influence of boiling heat, together with the exclusion of air. By this experiment he believed he had adduced the proof that air was to be regarded as the principal co-operative agent in fermentation and putrefaction.

Schwann was the first who regarded the yeast as a living plant. He knew that fermentation and putrefaction are suppressed by the application of high temperatures, for the reason that the living organisms that excited these phenomena were not able to stand heat. Among others, he adduced the following experiment: Into bottles filled with food-stuffs rendered germ-free by the application of boiling heat he conducted air which had previously been passed through red-hot tubes and thereby rendered sterile. As the food-stuffs subjected to this treatment showed good keeping qualities, the proof was thereby adduced that not the air in itself, but the germs mixed with it, were to be regarded as the true causes of putrefaction and fermentation.

During the following decade we find a fierce dispute raging between the representatives of the vitalistic theory of fermentation and their opponents, whose principal champion was Pasteur on the one hand, and Liebig on the other.

In all the investigations of Liebig he gives expression to the idea that yeast is a nitrogenous substance, which possesses the property of causing fermentation in other substances—that it is a contact substance which transmits the movement present to a small extent among its own molecules, in a higher degree upon the fermenting substance.

Pasteur represented the view that all fermentation and putrefaction were to be regarded as the vitalistic function of certain living organisms. Without life, no fermentation. He produced evidence to show that in lactic acid fermentation, the sole cause was a microscopic fungus, the lactic acid bacillus. He succeeded in proving the presence of the fungus in butyric acid fermentation, and likewise in the vinegar fermentation of wine. He proved, furthermore, that the most important and most significant fermentation, the alcoholic, i. e., the conversion of sugar or starch into alcohol and carbonic acid, is induced by the living cells of the fungus saccharomyces cerevisiæ. The living yeast fungus requires oxygen for its subsistence, which, instead of deriving it from the air like other plants, it extracts from the sugar, thereby causing the splitting up of the sugar molecule. Pasteur did not unreservedly give expression to the opinion that sugar was taken up by the yeast as a nutrient material, giving off alcohol and carbonic acid as products of assimilation. He, indeed, left room for the possibility that the yeast was the creator of an enzyme, which on its part accomplished the decomposition of the sugar. Yet nevertheless, "no fermentation without the simultaneous presence of living organisms."

But, however alluringly simple the conception was, that the albuminoids of the fermentation fungi bore within themselves the fermentative power, and however close approximations to the truth the various theories were, experiment had not up to that time proved it; they had not till then succeeded in isolating out of the yeast a fermentation-generating enzyme.

It was Büchner who, in 1896, accomplished this. In his investigations he started from the conception of the microscopic structure of the yeast fungus. The cells of the saccharomyces cerevisiæ are minute bubbles, in whose midst is the cell-body or the protoplasm. The cell-body is surrounded by a minute skin, the cell membrane, through which the absorption of food and the excretion of products of assimilation are carried on. It was, however, impossible to obtain the cell-body or protoplasm alone, by removing the cell membrane. Büchner conducted his operations for this purpose as follows: The yeast was thoroughly mixed with sand and kieselguhr, a fine infusorial earth, and vigorously ground, whereby he succeeded in bursting the cell membrane. He thus obtained a pasty mass, from which by pressing under a strong pressure, the expressed liquid, i. e., the contents of the protoplasm cells, was derived. This pressed out liquid contains the same enzymes as the living yeast cells, particularly the zymase. The liquid is capable, exactly like the living yeast itself, of inducing alcoholic fermentation in sugar.

The expressed liquid itself, however, does not keep for a very long time, and after standing for a short while loses its fermentative powers. Under low temperature it may, however, be evaporated to dryness, and there is thus obtained a hard, whitish mass, which retains its fermentative power unchanged for a very long time. Furthermore, by precipitation with alcohol and ether a substance can be obtained from the expressed liquid, which possesses enduring and stable fermentative properties. From this again, by means of glycerin, the purer enzyme can be extracted, and this extract is also capable of again setting sugar solution in fermentation. The merit of Büchner is, that he definitely disunited the phenomenon of fermentation from the vitalistic process of the yeast.

In like manner the isolation of the active enzyme from the butyric acid and acetic acid bacteria was accomplished.

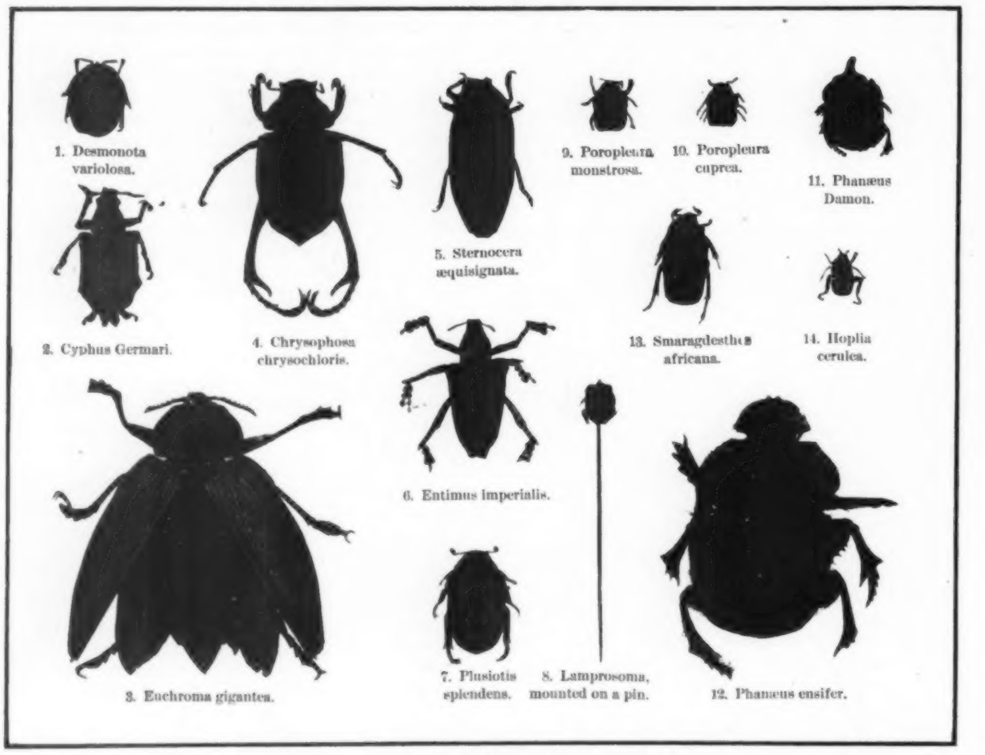
The discovery of zymase as a cause of fermentation marks a new epoch in physiological chemistry, which is not limited merely to the theory and practice of the science of fermentation, but extends into the domain of the phenomena of organic life. Various researches have already been undertaken in which it was attempted to reduce apparently complicated vitalistic phenomena to comparatively simple enzymatic influences, and the field of assimilation in organisms opens up auspicious and significant prospects.—Dr. P. Martens in Pure Products.

To Stain Ivory Coral Color.—The ivory is allowed to lie for a short time in nitric acid; rinse the acid off with water and boil the ivory, until the desired coral color is obtained, in a concentrated solution of carmine in spirits of sal-ammoniac, which has previously been diluted with 1,000 parts of water.

DECORATIVE INSECTS.

BUGS THAT SERVE AS ADORNMENTS.

AMONG the objects with which human beings adorn their persons are various brightly colored beetles. The most familiar of these decorative insects is the so-called "Brazilian beetle" (*Desmonota variolosa*, Fig. 1), which feeds upon the coffee plant. Set in gold



FIGS. 1 TO 14.—DECORATIVE INSECTS.

(Fig. 15) it appears in brooches, pins, sleeve buttons, earrings, and bracelets. The dead beetle is so hard that it must be perforated with a steel needle before it can be mounted in a collection. Still more suitable for brooches are the tropical *Buprestidæ* which glow with brilliant metallic colors. The largest of the family, the South American *Euchroma gigantea* (Fig. 3) is highly prized by the Indians of the west coast of South America, who sew its iridescent red, green, and gold wing covers on cloth and thus fashion a cuirass more dazzling than Lohengrin's silver shield. The Jivaros of Ecuador make necklaces and enormous ear ornaments (Fig. 16) of these wing covers, combined with those of a species of rose chafer. The wing covers are so hard that they clink like metal when the wearer runs or dances.

Another notable member of the family is the *Sternocera æquisignata* (Fig. 5), the wing covers of which are employed by the natives of Ceylon in the adornment of elaborate and artistic bed covers (Fig. 17).

FIG. 16.—EAR ORNAMENT COMPOSED OF WING COVERS OF EUCHROMA AND CHRYSOPHORA.

South American cotton plants are infested with a weevil called the jeweled beetle (*Entimus imperialis*, Figs. 6 and 18) which appears in sunlight as if it were studded with gems, owing to the effect of the numerous green furrows and depressions which half cover its black body. In Brazil this and another weevil (*Cyphus Germari*, Fig. 2) are often set in brooches, and small leaf runners of the genus *Lamprosoma* (Fig. 8) which surpass the finest opal in play of color—gold, green, and red—are employed as earrings and pins (Fig. 19). Figs. 9 and 10 show two species of the nearly allied genus *Poropleura*, which in form and color resemble, respectively, a cut ruby and a dark green zircon, and are consequently highly valued as ornaments.

Some European rose chafers are very brilliant and

FIG. 15.—DESMONOTA IN VARIOUS SETTINGS.

some exotic species furnish gorgeous ornamental objects. One species (*Chrysophora chrysochloris*) has already been mentioned (Fig. 16). Still more striking in appearance is the rare *Plusiotis splendens* (Fig. 7) to which the name gold beetle is eminently appropriate, as almost every part of the insect appears as if made of solid gold, highly polished. A good specimen costs $2.50 and a silver-hued species of the same genus sells for $15, for it is difficult to obtain as it flies only at night. Yet it must occasionally occur in large swarms, for great numbers of the beetles were once found, half drowned and helpless, on the shore of a volcanic lake in Central America after a nocturnal thunderstorm. The golden species was first discovered by Humboldt in Peru. It is of a brilliant greenish golden hue, with the exception of the posterior legs, which are marked with bright red and steel blue. It was long a great rarity in collections but it has recently been found in considerable numbers in Colombia.

The beautiful African emerald beetle (*Smaragdesthes africana*, Fig. 13) is found on flowering shrubs in Togoland during the rainy season, from May to October. Dr. Otto, who caught thirteen specimens and had one of them set in a brooch (Fig. 20) by a native goldsmith, told the writer that the well-to-do native

FIG. 18.—JEWELED BEETLE. (ENTIMUS IMPERIALIS.

women, who wear European dress with a profusion of jewelry, use many of these beetles as ornaments.

Ornamental insects exist even in Europe. A small, light-blue beetle (*Hoplia cerulea*, Fig. 14) which closely resembles the common garden leaf beetle (*Phyllopertha horticola*) is found in the south of France, where its collection for decorative use is so lucrative an occupation that the natives regard every foreign entomologist as an enemy, and seek to discourage him by interposing obstacles and even by throwing stones. The native collectors take great care not to kill the females. These are less brilliant than the males, which exceed them in number in the ratio of 50 to 1, or, according to some accounts, 100 to 1. The pretty little insect is an article of worldwide commerce, and is offered as an indigenous species by dealers in Rio, Port Said, and Batavia. It was formerly much used by milliners in connection with artificial flowers, but is now more often seen in a florist's window, nestling on the bosom of a rose (Fig. 21).

In South America even the disreputable burying beetles or dung bettles are used as ornaments, for which some species of *Phanæus* (Figs. 11, 12, and 22) are very well adapted, because of their strange shapes and bright metallic luster. Although buzzing beetles, like hangmen, are abhorred on account of their occupation, they are the most interesting and intelligent of all beetles. Their life history has been studied especially by Fabre and Ohaus. All the species rear their young with more or less care. The large European species known as the great horse beetle bores a vertical hole in the ground beneath or near a heap of horse dung, lays an egg in the hole and fills the latter with dung. The spring horse beetle makes more elaborate preparation for its young by sinking a conical shaft, two inches deep, and extending several horizontal galleries to a distance of eight inches from the bottom of the shaft. An egg and a sausage-shaped mass of tough, tightly-compacted dung are placed in each gallery, which is then filled with soft dung. The

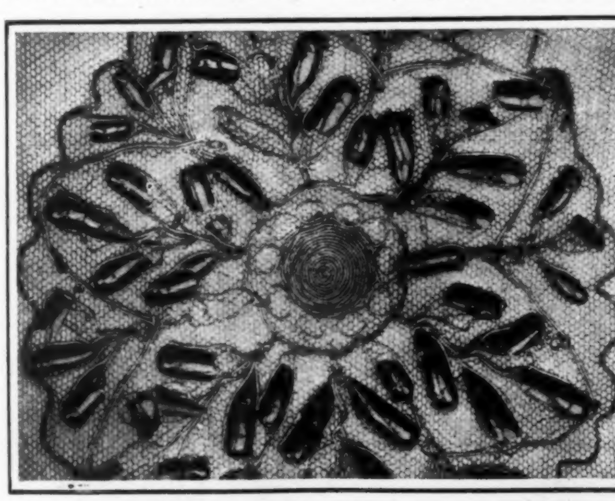


FIG. 17.—SINGHALESE BED COVER DECORATED WITH WING COVERS OF STERNOCERA.

"sausage," which is destined to serve as food for the larva, is black on the surface and green inside, and about two inches long.

Of the burying beetles that lay their eggs in balls of dung the most remarkable and most celebrated is the Mediterranean species *Scarabaeus sacer*. This is the sacred scarab of the ancient Egyptians, who saw in the insect and its actions the embodiment of martial valor, of the sun, and even of the Creator. Stone scarabs of colossal size were placed in temples, and

FIG. 19.—BEETLES MOUNTED AS BROOCHES AND EARRINGS.

smaller ones, usually of carnelian or of burned clay, were used at first as amulets and later as ornaments and seals. They were usually bored lengthwise, so that they could be strung like beads. Scarabs carved out of precious and other stones are found in Asia, Greece, and Etruria, as well as in Egypt, and are fashionable ornaments in America at the present day. The ancient Romans employed the beetle itself as a talisman and Pliny recommends the wearing of one as a preventive of quartan fever.

The development of this curious insect has lately been investigated thoroughly by Fabre, with the aid of a shepherd who, seeing a beetle emerge from the ground, dug and found a pear-shaped object as hard and smooth as if it had been turned on a lathe. It was composed of sheep dung and buried in its small end was found the egg of the beetle, which Fabre had sought in vain for twenty years. This discovery proved that the scarabaeus makes two sorts of pellets of dung, one of which serves as food and nursery for the young brood, the other as food for the parent.

FIG. 22.—BURYING BEETLES (PHANÆUS).

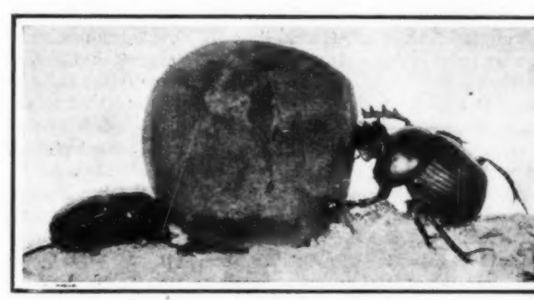


FIG. 23.—SCARABS BURYING A FOOD PELLET.

The round balls, which never contain eggs or larvæ, are built up, kneaded, shaped, and polished with the insect's forelegs and feet, which are used like arms and hands. The ball is then rolled away to a convenient hiding place and buried in the ground for future use as food. In this operation the beetle walks backward on its posterior feet and pulls the ball with its forelegs. Sometimes the possession of the ball is disputed by another beetle and is determined by combat. Probably the interior substance of the ball, which is tightly compressed and enveloped in a crust which hardens rapidly, is made more nutritious by a process of fermentation. When famished, however, the beetle eats fresh dung, without wasting time in this elaborate preparation. Hence many observers think that the making and rolling of balls is a sort of amusement, like the raccoon's habit of playing with a piece of meat after its hunger has been satisfied. In 1905 Neumann observed two large scarabs engaged in burying a pellet, near the ruins of Paestum (Fig. 23). One of the beetles held the ball with its forefeet while the other scraped sand from beneath the ball so that it gradually sank into the ground.

All these operations are performed in daylight, but the brood pellet, which was first discovered by the French shepherd boy, is always made at night. Both parents take part in the work, in which they exhibit a remarkable degree of intelligence. For the material of the pellet, which is to serve as food for the young, they always select the dung of sheep, which is softer, more nutritious, and more digestible than that of horses or cattle. After making a large globular pellet, the beetles excavate a vertical shaft, four inches deep, terminating in a wide gallery running obliquely downward, in which the pellet is placed. The male parent then abandons the work and the female tears the pellet to pieces, examines it carefully, destroys every living organism that it contains, and makes it over into a new pellet as round and smooth as a bullet. Then she occupies two days in making a little depression at the top of the pellet, depositing her single egg and working the rim of the depression over it, to form a little mound (Fig. 24). Thus is formed the pear-shaped brood pellet in which the egg hatches and the larva develops, emerging as a perfect insect at the end of four weeks.

A very interesting incident was witnessed by a German artist in Italy. A beetle, unable to dislodge its pellet from a hole into which it had rolled, went off to a neighboring dunghill and shortly returned with three companions. All four beetles worked together to get the ball out of the hole and when the task was accomplished three of them went back to the dunghill, while the fourth dragged the ball onward. Was this instinct or reason?

Some species of *Phanæus* are remarkable for the peculiarity that they are not strict vegetarians, like the European burying beetles, but occasionally eat animal food and appear to prefer it. *Phanæus milon*, which is commonly found under putrefying carcasses of dogs, cats, and fowls, in Uruguay and the adjacent provinces of Brazil and Argentina, even makes its brood pellets of animal matter. Fabre has pictured and described such a pellet, which he found in the earth beneath the carcass of an owl. It was chocolate colored and very hard and contained a nucleus composed of bits of flesh, bone, and down, mixed with mud. The nucleus was covered by a shell, three-fourths inch thick, composed entirely of earthy matter. Pertz has found this species and two others under dead fishes and snakes, but it is found also under dunghills. It is probable that most of the American burying beetles lived almost exclusively on animal food before the

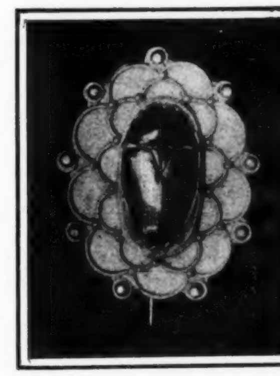


FIG. 20.—BROOCH WITH AFRICAN EMERALD BEETLE (SMARAGDESTHES).

continent was discovered, and horses, cattle, and sheep were introduced by Europeans, for the native herbivorous mammals were few in number. This, however, was not always the case. Horses, elephants, tapirs, ruminants, and edentata abounded in the tertiary period. This was the golden age of the burying beetles, which would doubtless have perished with their mammalian contemporaries if they had not been able to adapt themselves to an animal diet.

Living insects are worn as ornaments in South and Central America. *Zopherus Bremei*, a beetle which is found lurking in old walls in Central America, is worn by native girls as an amulet, to ward off evil spirits. The beetle is encircled by a band of gold which is fastened to a fine gold chain (Fig. 25). This singular "bosom friend" is cherished with great care, for its wonderful golden luster departs with its life, and its death, furthermore, is regarded as an evil omen. Fortunately, it is very tenacious of life, being able to exist without food for two years, according to report.

Another living ornament is the cocujo or Brazilian firefly (*Pyrophorus noctilucus*, Fig. 26) which emits strong luminescence from the abdomen and from two yellow prominences on the thorax. It is attracted and caught, at night, with the aid of a glowing coal which is waved in the air. The insects are kept in little wire cages, fed with bits of sugar cane, and bathed twice a day, in order to increase the luminescence, which is

FIG. 21.—DEAD BEETLES (HOPLIA) ON LIVING ROSES.

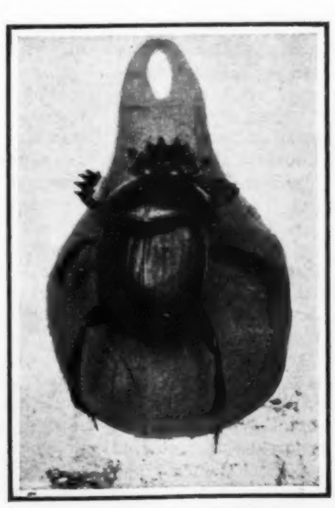


FIG. 24.—SCARAB WITH BROOD PELLET.

FIG. 25.—A LIVE BEETLE (ZOPHERUS) AS A NECK ORNAMENT.

FIG. 26.—COCUJO OR BRAZILIAN FIRE FLY (PYROPHORUS NOCTILUCUS).

sometimes sufficient for the reading of fine print. The larva of the cocujo is destructive to the roots of the sugar cane and is also found in rotten wood. A few larvæ have come to Europe in cargoes of timber. A flying luminous cocujo almost created a panic in a suburb of Paris in 1766. The light of the cocujo is utilized in various ways, but most commonly by imprisoning the insects in a perforated gourd. It produces its finest effect, however, when it is inclosed in a pouch of gauze and worn in the hair or on the bosom of a fair lady.—Translated for SCIENTIFIC AMERICAN SUPPLEMENT from Illustrirte Zeitung.

THE GEOLOGY OF THE INNER EARTH.*

THE FORMATION OF IRON ORES.

BY PROF. J. W. GREGORY, F.R.S.

THE modern science of geology may be said to be just a century old. With fine self-restraint its founders restricted their work to observing the surface of the earth; and so successfully have they worked that we now have geological maps of a wider area than was known to geographers of a century ago. Now that this geological survey of the earth is in rapid progress it is not surprising to find that the center of geological interest is shifting to the deeper regions of the earth's crust and to the problems of applied geology. The secrets of these deeper regions are both of scientific and economic interest. They are of scientific importance, for it is now generally recognized that the main plan of the earth's geography and the essential characters of the successive geological systems are the result of internal movements. The relative importance of those restless external agents that we can watch, denuding here and depositing there, has been exaggerated; probably they do little more than soften the outlines due to the silent heavings produced by the colossal energies of the inner earth.

The study of the deeper layers of the crust is of economic interest, for, with keener competition between increasing populations and with the exhaustion of the most easily used resources of field and mine, there is growing need for the better utilization of soils and waters, and for the pursuit of deeper deposits of ore.

If a shaft be sunk at any point on the earth's surface, a formation of Archæan schists and gneisses would probably always be reached; and, working backward, geological methods always fail at last—in primæval, Archæan darkness. The Archæan rocks still hide from us the earlier period of the earth's history, including that of all rocks which now lie beneath them. But already there are indications that the mystery of the "beyond" is not so impenetrable as it seemed.

The eighteenth century explained the history of the earth by the nebular hypothesis of Laplace. Geologists respectfully adopted this idea from the astronomers. The resulting theory represented the earth as originally a glowing cloud of incandescent gas, which slowly cooled, until an irregular crust of rock formed around a gaseous or molten core; as the surface grew cooler, the depressions in the crust were filled with water from the condensing vapor, forming oceans which became habitable as the temperature further fell. The whole earth was thought to have had a long period with a universal tropical climate. Still further cooling had established our climatic zones; and it was predicted that in time the polar cold would creep outward, driving all living beings toward the equator, until at length the whole earth, like the moon, would become lifeless through cold, as it had once been uninhabitable through heat. This theory has permanently impressed itself on geological terminology; and its corollaries, secular refrigeration and the contortion of the shrinking crust, once dominated discussions concerning climatic history and the formation of mountain chains. This nebular hypothesis, however, we are now told, is mathematically improbable, or even impossible; and it is only consistent with the facts of geology on the assumption that, in proportion to the age of the world, the whole of geological time is so insignificant that the secular refrigeration during it is quite inappreciable. Geology cannot confirm or correct the theory.

The theory of the gaseous nebula has been probably of more hindrance than help to geologists; its successors, the meteoritic hypothesis of Lockyer and the planetismal theory of Chamberlin, are of far more practical use to us, and they give a history of the world consistent with the actual records of geology. According to Sir Norman Lockyer's meteoritic hypothesis, nebulæ, comets, and many so-called stars consist of swarms of meteorites which, though normally cold and dark, are heated by repeated collisions, and so become luminous. They may even be volatilized into glowing and meteoric vapor; but in time this heat is dissipated, and the force of gravity condenses a meteoritic swarm into a single globe. Some of the swarms are, says Lockyer, "truly members of the solar system," and some of them travel around the sun in nearly circular orbits, like planets. They may be regarded as infinitesimal planets, and so Chamberlin calls them planetismals.

The planetismal theory is a development of the meteoritic theory, and presents it in an especially attractive guise. It regards meteorites as very sparsely distributed through space, and gravity as powerless to collect them into dense groups. So it assigns the parentage of the solar system to a spiral nebula composed of planetismals, and the planets as formed from knots in the nebula, where many planetismals had been concentrated near the intersections of their orbits. These groups of meteorites, already as solid as a swarm of bees, were then packed closer by the influence of gravity, and the contracting mass was heated by the pressure, even above the normal melting-point of the material, which was kept rigid by the weight of the overlying layers.

This theory has the recommendation of being consistent with the history of the earth as interpreted by Geology. For whereas the nebular hypothesis represents the earth as having been originally intensely hot, and having persistently cooled, yet geological records show that an extensive low-level glaciation occurred in Cambrian times in low latitudes in South Australia; indeed, it seems probable that, in spite of many great local variations, the average climate of the whole world has remained fairly constant throughout geological time. Whereas it has often been represented, in accordance with the nebular theory, that volcanic action has steadily waned, owing to the lowering of the earth's internal fires and the constant thickening of its crust, yet epochs of intense volcanic action have recurred throughout the world's history, separated by periods of comparative quiescence. Whereas it has been assumed, as a corollary to the nebular theory, that the force which uplifted mountain chains was the crumpling of the crust owing to the contraction of the internal mass, yet observation reveals that the crust has been corrugated, and fold mountains formed by contraction to an extent far greater than secular cooling can explain.

This planetismal hypothesis is not only consistent with geological records, but also with the known facts as to the internal composition of the earth and the structure of extra-terrestrial bodies as revealed by meteorites. Meteorites are of two main kinds—the meteoric irons, which consist of nickel iron, and stony meteorites, which are composed of basic minerals. Some of the stony meteorites have been shattered into fault breccias, showing that they are fragments of larger bodies which were subject to internal movements, like those that have formed crush conglomerates in the crust of the earth. Those stony meteorites, therefore, both in composition and structure resemble the rocks in the comparatively shallow fracture zone of the earth's crust. The nickel-iron meteorites, on the other hand, represent the barysphere beneath the crust.

The earth appears to consist of material similar to that of the two types of meteorites; but whether the proportions of the two materials in the earth represent their proportions in other bodies and in meteoric swarms is problematical. There appear to be no satisfactory data for an estimate of the relative abundance in space of the iron and stony meteoric material. Stony meteorites have been seen to fall far more frequently than iron meteorites; but the largest known meteorites are of the nickel-iron group, although this material, in moist climates, very soon decays. The most trustworthy indication as to the relative amounts of the stony and nickel-iron meteorites is given by a comparison of the weight of the two types of material in meteorites of which the fall was seen. The available evidence suggests that the stony meteorites fall the more frequently on the earth, but the meteoric irons come in such large masses that they outbalance the showers of the smaller stones.

We might have expected help from another source in examining what lies below the Archæan rocks. Cannot the relative proportions of the stony and metallic constituents in the earth help us? Unfortunately, this proportion is uncertain. The best-established fact about the interior of the earth is that its materials are much heavier than those of its crust. The specific gravity of the earth as a whole is about 5.67; the specific gravity of the materials of the crust may be taken as about 2.5, while that of the heavier basic rocks is only about 3.0. Hence the earth as a whole weighs about twice as much as it would do, if it were built of materials having the same density as those which form the crust.

Two explanations of the greater internal weight of the earth have been given. According to one, the earth is composed throughout of the same material, and the internal mass is only heavier because it is compressed by the weight of the overlying crust. According to the alternative or segregation theory, the difference in density is explained as due to a difference in composition; the interior of the earth is thought to be heavier owing to the concentration of metals within it. The probability of this metallic interior has been advanced from several lines of evidence; and the assumed metallic mass has received from Posepny the name of the "barysphere," or heavy sphere. According to this view the earth is essentially a huge ball of iron, which, like modern projectiles, is hardened with nickel; and it is covered by a stony crust, the materials of which were primarily separated from the metallic mass, like the slag formed on a ball of solidifying iron in a puddling furnace.

It has been objected that the weight of the earth is not great enough for much of it to be composed of metallic iron or of meteoritic material. The specific gravity of iron under the pressure at the earth's surface is about 7.7, and it would be even greater when compressed in the interior. But the barysphere is doubtless impregnated with much stony material that would lessen its weight. An estimate by Farrington (1897) of the average specific gravity of the meteorites of which the fall had been recorded is only 3.69. According to the Rev. E. Hill (1885) the mean specific gravity of all the meteorites in the British Museum was 4.5; and, though Mr. Hill duly considered the effect of compression, he concluded that "the density of the earth is perfectly consistent with its being an aggregation of meteoric materials." Moreover, within the metallic barysphere there may be a core of lighter material; for earthquake waves travel more slowly in the central core of the earth than in the intermediate zone, or are even suppressed altogether there; hence the center of the earth may be occupied by matter less compact than that of the shell around it; and, according to Oldham's calculations, the light central core occupies two-fifths of the diameter of the earth.

The evidence of density alone, therefore, gives no convincing evidence of the nature of the earth's interior; and geologists have been left with no conclusive reason for choosing between the condensation and segregation theories. Radio-activity has, however, unexpectedly come to their aid, and has disclosed a further striking resemblance between the internal mass of the earth and the iron meteorites. It has supplied direct evidence about the constituents of the earth at depths which have hitherto been far beyond the range of observation. Mr. Strutt has shown that radium is probably limited within the earth to the depth of 45 miles; that the deeper-lying material is free from radium; and that this substance is not found in iron meteorites. The agreement in radioactive properties between the iron meteorites and the interior of the earth is an additional and weighty argument in favor of the view that the earth is largely composed of nickel iron.

The physical condition in which the material exists is now of secondary interest. The old controversy as to whether the earth has a molten interior inclosed within a solid shell has lost its importance, because it has become a mere matter of definition of terms. The facts which led geologists to believe that the interior of the earth is fluid are consistent with those which prove that the earth is more rigid than a globe of steel. For under the immense pressure within the earth the materials can transmit vibrations and resist compression like a solid; but they can change their shape as easily as a fluid. They are fluid just as lead is when it is forced to flow from a hydraulic

* Abstract of an address delivered before the British Association for the Advancement of Science.

press. Not only are geologists now justified in their belief that the deeper layers of the earth's crust are in a state of fluxion, but, according to Arrhenius (1900), the earth is solid only to the depth of 25 miles, below which is a liquid zone extending to the depth of 190 miles; and below that level, he tells us, "the temperature must, without doubt, exceed the critical temperature of all known substances, and at this depth the liquid magma passes gradually to a gaseous magma." This distinguished physicist gives a description of the earth's interior which reminds us of the views of the early geologists. Arrhenius's theory rests, however, on the existence within the earth of exalted temperatures; and this assumption a geologist may now hesitate to accept with less risk of getting into disgrace than he would have run a few years ago. It is improbable that the rapid increase of heat with depth which is observed near the surface should continue below the lithosphere; for, if the earth consists in the main of iron, even though it be arranged as a mesh containing silicates in the interspaces, the heat conductivity might be sufficient to keep the whole metallic sphere at a nearly equal temperature. Here, again, Mr. Strutt's work on radioactivity is in full agreement with the requirements of geologists, for he estimates that below a crust 45 miles thick the earth has a uniform temperature of only 1,500 deg. C. Whether the further conclusion, that this heat is due to the action of the radium in the crust, be established or not, it is gratifying to hear a physicist arguing in favor of a moderate and uniform internal temperature.

All that the actual observations prove and that geological theories require is that the material within the earth be intensely hot, and that it lie under such overwhelming pressure that it would as readily change its form and as quickly fill up an accessible cavity as any liquid would do. Whether such a condition is to be described as solid, liquid, or gaseous is of little concern to geologists.

The modern view of the structure of the earth adds greatly to the interest of its study, for it recognizes the world as an individual entity of which both the geological structure and the history have to be considered as a whole.

The irregular individual shape of the earth is expressed by its description as a geoid. The processes which have produced its varying shape have also controlled its geological history and evolution, for they cause disturbances of the crust, which affect the whole earth simultaneously; and so the geographical agents are given similar work and powers at the same time in different places.

Hence there is a remarkable world-wide uniformity in the general characters of the sedimentary deposits of each of the geological systems. The last pre-Cambrian system includes thick masses of felspathic sandstones alike in Scotland, Scandinavia, the United States, and perhaps also the Rand. The Cambrian has its greywackes and coarse slates and its numerous phosphatic limestones; the Ordovician its prevalent shales and slates; the Silurian its episodal limestones and shales. The Devonian has its wide areas of old red sandstones as a continental type, while its marine representatives show the prevalence of coarse grits and sandstones in the lower series, of limestones and slates in the middle series, and the recurrence of sandstones in the upper series; and this sequence occurs alike in northwestern Europe, in America, and Australia. The Carboniferous contains the first regional beds of thick limestone and the first important coal measures. In the Mesozoic era we owe to Suess the demonstration of the world-wide influence of those marine encroachments or "transgressions" whereby the great continents of the Trias were gradually submerged by the rising sea.

Speaking generally, there is a remarkable lithological resemblance between contemporary formations in all parts of the world. This fact had been often remarked, but was usually dismissed as due to a number of local isolated coincidences of no special significance. But the coincidences are too numerous and too striking to be thus lightly dismissed. They are among the indications that the main earth-changes have been due to world-wide causes, which led to the predominance of the same types of sedimentary rocks during the same period in many regions of the world.

The conditions that govern the geological evolution and general geography of the earth are probably due to the interaction between the earth's crust and the contracting interior; they may take place as slow changes in the form of the earth, causing the slow rising or lowering of the sea surface, or the slow uplift or depression of regions of the earth's crust; or they may give rise to periods of violent volcanic action in many parts of the earth, between which may be long periods of quiescence. The geographical effects of changes in the earth's quivering mass affect distant regions at the same time. Therefore the landmarks of physical geology will probably be found to give more precise evidence as to geological synchronism than those of Palæontology.

Belief in the earth's internal fires was most faithfully held among geologists by the Plutonists of the eighteenth century, and repudiated with equal thoroughness by the Neptunists, who refused to concede that volcanic action was due to deep-seated cosmic causes. Thus Jameson in 1807 stoutly maintained that volcanoes were superficial phenomena due to the combustion of beds of coal beneath fusible rocks, such as basalt, and that the explosions were due to the sudden expansion of sea-water into steam by contact with the burning coal. Volcanoes, according to this view, were correctly described as burning mountains, giving forth fire, flame, and smoke. The extreme Neptunist and Plutonist schools have long since been extinct, but the controversy is not quite closed. The battlefield is practically restricted to economic geology, and the issue is the origin of some important ores.

Ore deposits present so many perplexing features that deep-seated igneous agencies were naturally invoked to explain them, and some of the most thoroughgoing champions of the igneous origin of ores make claims that remind us of the eighteenth-century Plutonists. The question is to some extent a matter of terms. Prof. Kemp limits the term "igneous" to materials formed by the direct consolidation of molten material; and this decision seems to be most convenient. For example, the quartzite that is so often found beneath a bed of basalt is due to hot alkaline water from the lava cementing the loose grains of sand; the process is an eruptive after-action, but it would be unusual to call such a quartzite an igneous rock.

That there are ores which are the products of direct igneous origin is now almost universally admitted. The mineral magnetite is a most valuable source of iron, and it is a constituent of most basic igneous rocks. If iron were a high-priced metal, such as tin or copper, of which ores containing one or three per cent are profitably worked, then basalt would be an ore of igneous origin. Under present commercial conditions, however, basalt cannot be regarded as an iron ore. But if the magnetite in a basic rock had been segregated into clots or masses large enough and pure enough to pay for mining, then they would be iron ores formed by igneous action. There are cases of such segregations large enough to be mined. The most famous is Taberg, a mountain in Smaland, near the southern end of Lake Wetter, in Sweden.

At Routivaara, in Swedish Lapland, there is a still larger mass of magnetite, which is claimed, in accordance with the descriptions of Petersson and Sjögren, to be due to segregation from the magma of the surrounding gabbro. This mass of magnetite is of colossal size, but it is of no present economic value, owing to its high percentage of titanium and its remote position.

An igneous origin is claimed by Prof. Högbom for some small masses of titaniferous magnetite in the island of Alnö, opposite Sundsvall, on the eastern coast of Sweden. This case is of interest, as the surrounding rock is not basic; it is a nepheline syenite, containing only 2 per cent of magnetite, which, however, has been concentrated in places, until some specimens (according to an analysis quoted by Prof. Högbom) contain as much as 64 per cent of magnetite, 9 per cent of ferrous oxide, and 12 per cent of titanic oxide. These Alnö magnetites are of no practical value, as they are too low in grade and too refractory in nature.

About 500 tons of the material has been smelted, but with unprofitable results, and the rest of the material quarried has been left on the shore. We may therefore accept the iron-bearing masses of Alnö and Routivaara, as well as that at Taberg, as due to magmatic segregation, without having conceded much as to the igneous formation of ores. The process in this case has formed rocks, rich in titaniferous magnetite, from which iron could be obtained, but rocks which no ironmaster is at present willing to buy as iron ore. Whether a basic igneous rock is to be regarded as an iron ore, or as only useful for road metal, depends on cost of treatment. The definition of the term "ore" is very elastic. Usually ore means a material which can be profitably worked as a source of metals under existing or practicable industrial conditions. According to this definition, the Swedish deposits of titaniferous magnetite are at present doubtfully within the category of iron ores.

The famous iron mines of Middle Sweden at Dannemorra, Norrberg, Grängesberg, and Persberg occur under different geological conditions; they work lenticles or bands of ores in metamorphic rocks, of which some are altered sediments; and the view has therefore been held by De Launay and Vogt that the ores also are altered sediments.

That ores are formed by igneous segregation of sufficient size and purity to be of economic importance is a theory which rests on two chief cases—the nickel ores of Sudbury in Canada and the iron ores of Swedish Lapland.

The nickel ores of Sudbury are the most important historically. They have been repeatedly claimed as of direct igneous origin, and the view was advocated before the association at the Johannesburg meeting by Prof. Coleman. The theory was stoutly opposed by Posepny in 1893, and Prof. Beck in 1901 described some of the brecciated ore, and showed that its metallic minerals are sharply separated from the barren rock. He held that such ore must have been formed, not only after the consolidation of the rock, but even after or during its subsequent metamorphism. The views of Posepny and Beck seem to have been established by additional microscopic study of the ores by C. W. Dickson (1903). He has shown that the sulphides are separated from the barren rock by sharp boundaries, and without any indication of a passage between them; that the fragments of ore in the rock have sharp corners, whereas, had they grown in a molten magma, the angles would have been rounded, and the faces corroded. Most of the ore, moreover, occurs as a cement filling interspaces between broken fragments of barren rock and along planes of shearing. The Sudbury ores, therefore, appear to have been deposited from solution during or after the brecciation of the rocks in which they occur, and long after their first consolidation. If Dickson's facts be right, the Sudbury ores are necessarily aqueous and not igneous in origin.

The other important mining field of which the ores are claimed as of igneous origin is Swedish Lapland. Its ores are rich and the ore bodies colossal. One mine, Kirunavaara, yielded more than one and a half million tons of ore in 1906, and according to a recent agreement with the Swedish government the annual output of ore from that mine may be raised to three million tons by 1913.

The chief mining fields of Lapland, although situated to the north of the Arctic circle, have long been known; for some of them contain veins of copper which were worked in the seventeenth century. The iron ores, however, could not be used until a railway had been laid through the swamps of Lapland to carry the ores cheaply to the coast. In 1892 a railway was completed across Scandinavia, from the head of the Gulf of Bothnia at Lulea to an ice-free port at Narvik, on the Norwegian coast. This railway, the most northern in the world, passes the two great mining fields of Gellivara and Kiruna. The mining field of Kiruna is the larger and at present of the greater geological interest, as its structure is simpler and its rocks less altered.

The ore body at Kiruna outcrops along the crest of a ridge two miles long, and it is continued beneath Lake Luossajarvi to the smaller but still immense ore body of Luossavaara. At Kiruna the ore rises to the height of 816 feet above the surface of the lake, and it varies in thickness from 30 to 500 feet, with an average thickness of about 230 feet. According to a report by Prof. Walfried Petersson, Kirunavaara contains 200 million tons of ore above lake-level, and Luossavaara another 22½ million tons. The ore is high grade. According to Lundbohm 60 per cent of the trial pits showed a yield varying from 67 to 71 per cent of iron, and 21 per cent of them showed a yield from 60 to 67 per cent of iron. The average of nineteen analyses published in Prof. Petersson's recent report gives the contents of iron as 64.15 per cent. Unlike the Taberg and Routivaara ores, the percentage of titanium is very low; thus in nineteen analyses given by Petersson the average of titanic acid is only 0.23 per cent, and it varies in the specimens from 0.04 to 0.8 per cent.

Three main theories of the genesis of the Kiruna ores have been proposed. Their sedimentary origin was urged on the ground that they occur regularly interstratified in a series of altered sediment, and that the ores, therefore, are also sedimentary. This view may be promptly dismissed, since the adjacent rocks are igneous. According to a second theory the porphyrites above and below the iron ores are lava flows, and the ore was a superficial formation deposited in an interval between the volcanic eruptions. According to De Launay the iron was raised to the surface as emanations of iron chloride and iron sulphide; the iron was deposited as oxide, and most of it subsequently reduced to magnetite during the metamorphism of the district.

The third theory—that the ores are of direct igneous origin—has been maintained by Löfstrand, Högbom, and Stutzer; according to them the ores are segregations of magnetite from the acid igneous rocks in which they occur. The segregation theory has serious difficulties, and is faced by several obvious improbabilities. The ore occurs as a band nearly forty times as long as it is broad. It has the aspect, therefore, of a bed or a lode. The ore has not the granular, crystalline structure of an igneous rock like the hyperite of Taberg, but the aspect of a material deposited from solution or formed metasomatically. It is almost free from titanium.

The Kiruna ores do not impress one as of igneous formation. Their bed-like form, microscopic structure, and poverty in titanium are features in which they differ from those admittedly due to direct magmatic

segregation. Microscopic sections suggest that both the magnetite and apatite were deposited from solution and later than the consolidation of the underlying porphyrite, which the ore in part replaces. An examination of the field evidence supports the conclusions of De Launay and Bäckström as to the ore being a bedded deposit overlying a lava flow, but enlarged by secondary deposition.

This conclusion is perhaps economically disappointing. The possible existence of such vast segregations of iron in the acid igneous rocks has an important economic bearing. There is only too good reason to fear that the chief iron ores are comparatively limited in depth; for most of them have been formed by water containing oxygen and carbonic acid in solution, which has percolated downward from the surface. Ores thus formed are therefore restricted to the comparatively limited depths to which water can carry down these gases. On the theory, however, that these ores are primary segregations from deep-seated igneous rocks there need be no limit to their depth. They would rather tend to increase in size downward, while maintaining, or even improving, in the richness of their metallic contents. For these bodies might then be regarded as fragments of the metallic barysphere which have broken away from it and revolve around it like satellites floating in the rocky crust. On this conception these ore bodies would be of as great interest to the student of the earth's structure, as their existence would be reassuring to the ironmaster, haunted as he is by constant predictions of an iron famine at no distant date. It is no doubt true that many of the richest, most accessible, most cheaply mined, and most easily smelted iron ores have been exhausted. The black-band ironstone and the clay iron ores of the coal fields, which gave the British iron industry its early supremacy, now yield but a small proportion of the ores smelted in our furnaces. The Mesozoic beds of the English Midlands and of Yorkshire still supply large quantities of ore. Nevertheless the British iron industry is becoming increasingly dependent on foreign ores. So it would be interesting to find that the Scandinavian iron mines are not subject to the usual limits in depth. The typical iron deposits of Middle Sweden and of Gellivara will probably follow the general rule; but Kiruna may be an exception, and its ores may continue far downward along the surface of its sheet of porphyrite. The uncertainty in this case lies in the extent of the subsequent enrichment and enlargement of the bed; if most of the ore is due to secondary deposition, then it may be restricted to the comparatively shallow depths at which this process can act; and though that limit will be of no practical effect for a century or more to come, the ore deposit may be shallow as compared with gold mines.

The geological evidence may convince us that all the economically important iron ores are limited to shallower depths than lodes of gold, copper, and tin; but this conclusion should not make pessimists as to the future of the iron supply. In economic as in theoretical geology, we should have greater confidence in the value of geological evidence. Negative predictions are especially rash in regard to iron, it being the most abundant and widely distributed of all the metals. The geologist who knows the amount of iron in most basic rocks finds it difficult to realize the possibility of an iron famine. There are reserves of low grade and refractory materials which the fastidious ironmaster cannot now use, since competition restricts him to ores of exceptional richness and purity. When the latter fail, an unlimited quantity could be made available by concentration processes. The vast quantities of iron ores suitable for present methods of smelting in Australia, Africa, and India show that the practical question is that of supplies to existing iron-working localities, and not of the universal failure of iron ores.

TUPELO—A USEFUL NEW WOOD

The latest discoveries of valuable qualities in a formerly neglected species of tree resulted after an investigation of the tupelo gum which finds its home in the Southern swamps. Tupelo two years ago was little known and seldom used even in the parts of the country where it is most plentiful. In the cutting of cypress in the Gulf States, where tupelo is found in large quantities, the trees were disregarded. It was found that the prejudice then existing against the wood was caused by a lack of knowledge of its properties and lack of care in handling the material. The investigations carried on by the United States Forest Service have proved the value of the wood for a number of uses. The result of these studies largely removed the prejudices against this gum, and in a short time the demand for tupelo rapidly increased.

The wood is now widely used, not only in the States where it grows, but also in distant parts of the country, in the manufacture of wooden pumps, sounding boards for violins and organs, mantels and interior finishing, such as molding, door and window frames and door jambs. It is also manufactured into all kinds of lumber, including a good grade of edge grain flooring. Tupelo gum in the form of flooring was recently found competing successfully with Douglas fir in the Los Angeles market even though bearing a freight rate of 85 cents a hundredweight from its source of production in Louisiana.

ENGINEERING NOTES.

The personal element is the most difficult obstacle to overcome in the fight against smoke. Study of the requirements and a desire to obtain good results on the part of the firemen will do more to clear the air in cities than any other one influence. Well-designed furnaces may smoke to a greater or less degree, depending on the methods of the firemen, the kind or size of the coal, and the rate at which the coal is burned. They may be expected to give smokeless combustion when burning a suitable coal, except under unfavorable operating conditions.

Glass is not a substance that we can figure the strength of as we can a great many other things with which we are familiar. It varies greatly in itself. The strongest glass, as a rule, breaks into the greatest number of fragments. Comparing the strength of thin glass with thick, the former is relatively the stronger; this is a thing very often lost sight of. Then again as to the difference between rough plate and polished plate, we find polished plate the stronger. This is perhaps to be attributed to the fact that all these very fine surface hair cracks are polished out. These only go into the glass to a certain depth and when they are all or nearly all polished and ground off, there is less chance for some of them to form the basis of a crack, and thereby the glass is increased in strength. Tests have been made and some formulæ have been arrived at. As was to be expected they show very irregular results as to the strength of glass.

Within a recent period, efforts have been made to develop the natural resources of Lapland, and there seems to be a considerable economic future in store for this region, which is especially due to the large deposits of iron ore. A great step in advance in developing the country was the building of the trans-Lapland railroad, which was finished in 1903. With the annex lines which are now building, it will soon put Lapland in connection with Tornea in Finland, with St. Petersburg and with the eastern region. The Stockholm-Narvik railroad line, which runs north and south, has a length of 950 miles. The transverse east-west line starts from Lulea, a Swedish Lapland port on the Gulf of Bothnia, and ends at the Norwegian port of Narvik (290 miles) passing by the mines of Gellivara and Kiruna. These latter mines, which have been worked only since 1902, were known as long back as 1735. The ore is taken out from the surface in an open digging. Each day there are six trains of 28 cars of 38 tons sent to Narvik. The annual product of the mine is 1,400,000 tons. The town of Kiruna, with its attractive frame houses, has only four years' existence. M. Parmentier, secretary of the St. Quentin Geological Society, recently made an interesting conference at Paris upon the trans-Lapland railroad, in which he showed that Lapland, now connected with the international railroad system, will open a field for immigrants who can find remunerative work there.

A project is on foot in Germany for the transformation of the Kaiser Wilhelm canal, which runs from the North to the Baltic Sea, and upon which great hopes had been founded. In the idea of the constructors, a great part of the maritime navigation would abandon the Scandinavian straits in order to take this narrow waterway which has but little depth, where but a very slow speed can be obtained, at the same time paying a tax which is quite high and is designed to meet a part of the expense of the canal. Without doubt the traffic of the canal has developed since its opening, but this has been much more slowly than was supposed, and it is only at the present time, after twenty years of operating, that the canal can pay the expenses of keeping up and of operating, by means of its receipts. A certain number of large vessels having 25 feet draft have tried this waterway, but those which pass by the canal are becoming more rare, because the passage is full of danger and requires considerable time. It is now desired to modify the width of the canal (bottom width) which is only 72 feet, as well as the water depth, which is but 30 feet, also the end locks, which are now but 495 feet long by 82 feet wide. For this purpose an extensive project has been drawn up and it is now seeking for financial backing. In the first place, many curves will be rectified, replacing the radius of 3,960 feet by a 5,950-foot radius, the latter being indispensable for the ships which are to pass in the canal. The width will be increased to 145 feet and there will be a mean draft of 40 feet. It is even thought possible to carry the depth to 46 feet. The number of garages (side-ways) will be increased and this will permit a greater number of vessels to circulate at once, and they will be able to cross each other every six miles. At the Suez Canal, the garages are spaced every three miles, which is a great advantage. For the locks, there are provided corresponding changes, and they will have 1,090 feet length with a width of 150 feet, and the depth of water will be at least 40 feet. It is designed to suppress nearly all the drawbridges which retard navigation at present, and they will be replaced by high fixed viaducts. The present project is a vast one, and calls for an expenditure of at least $55,000,000.

TRADE NOTES AND FORMULÆ.

Leaking in Casks.—25 parts of fresh tallow, 20 parts of wax, 40 parts of lard, melted and thoroughly mixed. Cool the mixture, and while cooling add 25 parts of sifted ashes. Heat when using.

Label Adhesive for Bottles Stored in the Cellar.—A paste is made by boiling glue water and rye flour to which, while in a warm condition, for 1,000 parts of the mass, 30 parts of linseed oil varnish and 30 parts of thick turpentine are added.

To Take the Wood Taste Out of Barrels.—Fill the barrels with lime water, adding for each 14 gallons capacity about 178 grains of potash and allow them to stand six to eight days, after which they should be washed out with clean water. The fluid can be used over again, especially if to each new cask some more lime and potash be added.

Filling of Cracks and Dents in Wood.—White tissue paper is steeped and perfectly softened in water and by thorough kneading with glue, transformed into a paste, and by means of ochers (earth colors), colored as nearly as possible to the shade of the wood. To the paste calcined magnesia is then added and it is forced into the cracks or holes. This cement attaches itself very firmly to the wood and after drying retains its smooth surface.

Sympathetic Inks.—Dissolve in a flask, 1 part of nitrate of cobalt in 3 parts of nitric acid, at moderate heat. After the solution, add 2 parts of carbonate of potash and 1 part of common salt; thin the solution with pure water. Applied to the picture it is at first red, then, under the influence of heat, violet. Blue: 1 part of nitrate of cobalt dissolved in a flask in 3 parts of hydrochloric acid. The mixture is blue; by the addition of water changes to carmine red. On the picture, when warmed, it becomes blue again.

Cloissoné Enamel (process of ancient artists).—The outlines of the design to be executed in enamel are cut out in the metal plate in such a manner that between the limits of the colors in the enamel a narrow metal ribbon is left standing. The space within the outlines is worked out with the graving tool, the surfaces left standing being made as rough as possible. In the hollows, the mass, made into a thick paste with lavender oil or water, is placed and fused fast in the muffle, this process being frequently repeated. Finally the surface is ground smooth and polished.—Bersch.

Mixture for Colored Firework Stars.—White: 9 parts of saltpeter, 3 parts sulphur, 2 parts antimony. Red: 20 parts nitrate of strontia, 12 parts chlorate of potash, 11 parts sulphur, 2 parts carbon, 2 parts antimony, 1 part mastic. Blue: 20 parts chlorate of potash, 14 parts mountain blue (blue carbonate of copper), 12 parts sulphur, 1 part mastic. Yellow: 20 parts chlorate of potash, 10 parts bi-carbonate of soda, 5 parts sulphur, 1 part mastic. Green: 12 parts nitrate of baryta, 28 parts chlorate of potash, 15 parts sulphur, 1 part mastic. Violet: 9 parts chlorate of potash, 4 parts nitrate of strontia, 6 parts of sulphur, 1 part mountain blue, 1 part calomel, 1 part mastic.

To Make Ivory and Bone Permanently White.—Hydrated oxide of zinc is dissolved in ammonia and the ivory or bone laid in it. To remove the yellow tint, a few drops of an aqueous solution of blue vitriol is added, until the latter, on being shaken up, turns blue; after impregnation the object is repeatedly washed with cold water and dried in the air and polished. Zinc-oxide ammonia solution is prepared as follows: 40 parts by weight of water are mixed with 25 parts of pure zinc white, and after a quarter of an hour, 50 parts of concentrated hydrochloric acid is added. To the zinc solution, 150 parts of hot water is added, then gradually, stirring the while, caustic ammonia until the precipitated white hydrated oxide of zinc is dissolved.—Bersch.

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